Metal Progress

December 1957

Progress with TITANIUM

Announcing...

Two new Titanium alloys for high temperature applications

MST 821... *the highest strength weldable sheet & bar alloy in 400—1000°F range*

MST 2.5Al-16V... *the first readily formable, heat treatable sheet alloy*

Two new alloys developed by Mallory-Sharon now extend the high temperature usefulness of titanium.

MST 821 is a weldable sheet and bar material with exceptional high temperature strength. It offers strengths equivalent to similar titanium alloys at temperatures *two hundred degrees* higher, in the 400 to 1000°F range. MST 821 is thermally stable, and has good ductility and formability.

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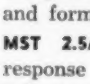

Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets

Metal Progress

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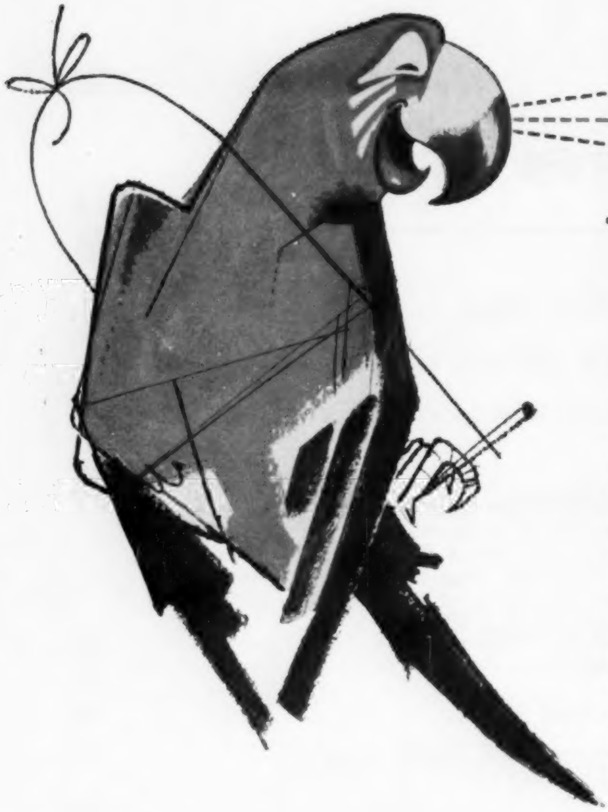

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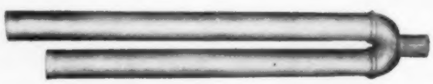

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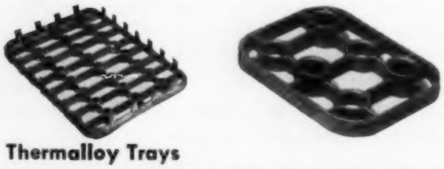

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Metal Progress

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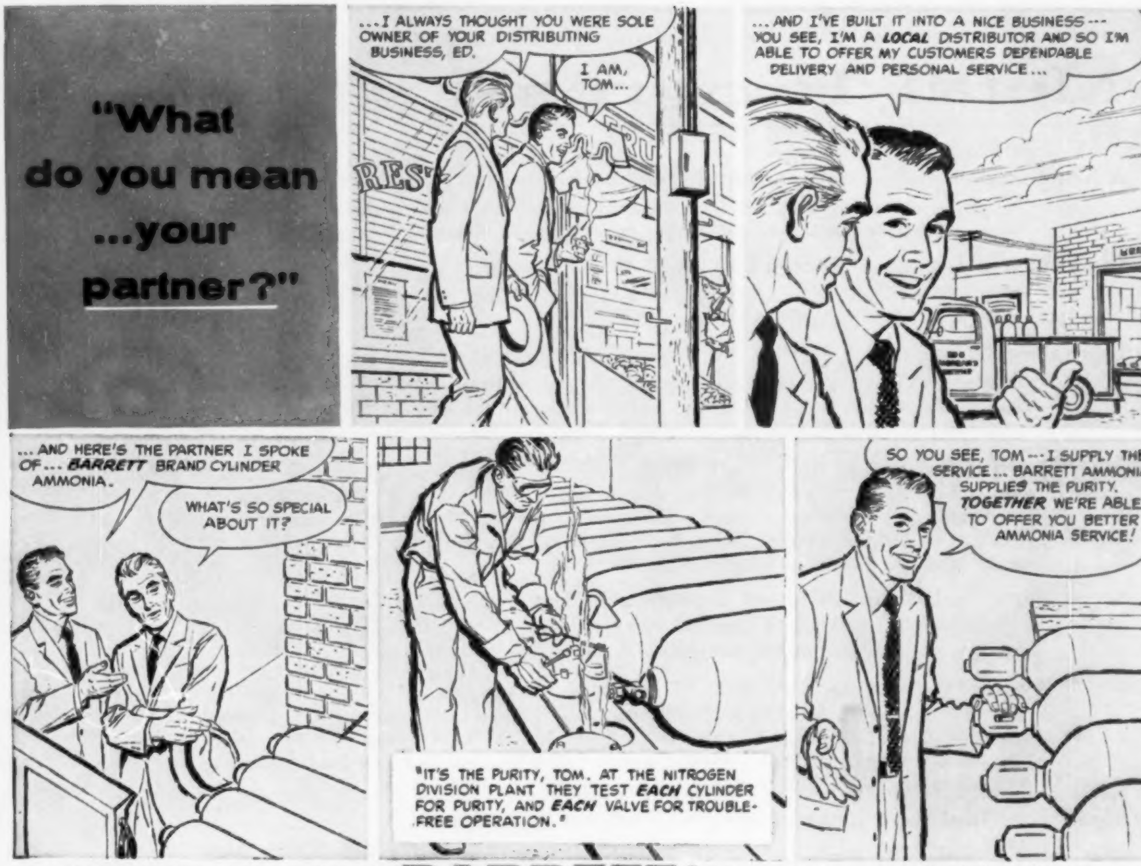

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As I was saying...

As I was saying to the Overseas and American Conferees at the "Farewell to America" Banquet of the Second World Metallurgical Congress, Palmer House, Chicago, Nov. 8, 1957:

The A.S.M. staff and I look with great joy and happiness toward the planning and arranging of a World Metallurgical Congress. It starts about two years in advance of your arrival. First is the study of the general scope and divisions of the Congress, and then come the preparation and mailing of the first announcements abroad.

Very soon after the first announcements of the 2nd W.M.C. were distributed, our hope that the tours and panel sessions in Chicago would be well attended was confirmed. Correspondence with the enrollees prepared us for the personal meeting soon to come.

We studied the positions, the interests and desires, and the products of the firms and institutions of the Overseas Conferees, and then selected from among the top American metallurgical scientists, A.S.M. members to be your counterparts, and to be the American Conferees.

The day of anticipation arrives — we meet you in New York and welcome you to America; you hear words of welcome, not only from the Society but from the chairman of the board of Republic Steel Corp., Mr. Charles M. White, representing the ferrous industry, and from I. W. Wilson, chairman of Aluminum Co. of America, representing the nonferrous industry.

The selection of plants for inspection for those going on tours again gives evidence of the open arms extended to you by industry, institutions, and the Government. We needed only to send a request to receive by return mail an approval of the visit.

Those visitors on the tours were joined in Chicago by an equal number of Overseas Conferees for this great 2nd W.M.C.

This Congress is now history. You have occupied a better position in which to judge and ascertain its value than I. I have been too close to it all. I have been absorbed in its fulfillment, but I could not help but feel the warmth and enthusiasm that pervaded this gathering.

This Congress was certainly well timed, coming at a period when changing world conditions activated the free nations into a desire to exchange and pool their scientific knowledge and achievement in common problems of mutual interest. (*Turn to page 6*)

As I was saying...

However, forming a brain power alliance is nothing new to the A.S.M. and to you Overseas Conferees. It was Detroit in '51, Chicago in '57, and I am pleased to announce that the 3rd World Metallurgical Congress under the sole auspices of the A.S.M. will be held the first week in November in Chicago in 1962.

And now the 2nd W.M.C. is nearing its end. The curtain is slowly descending, and will soon leave us only our memories. But what beautiful and precious memories they will be; the realization of the fruits of the pooling of our scientific knowledge; how all of our hearts melted in a warmth of friendliness; how all have been engulfed in a spirit of warmth and understanding; the thoughts of how truly wonderful this world would be if this "something" created by this Congress would permeate all mankind; how human understanding and appreciation prevailed among the conferees; a memory of the dynamic warmth and magnetism that emphasizes man's best feeling to man.

These, my dear friends, are the memories I hope may be yours in the coming years — whenever your thoughts return to your visit to America; I can assure you these Gifts of the Congress will live forever in the memories of the American Conferees.

And so the curtain has descended. A screen has been erected between the past and the present. And as I had the honor to open and close the first W.M.C., and also to open the 2nd W.M.C. in New York, so now I am granted the high honor to close it. I shall do so by repeating the closure of the First Congress:

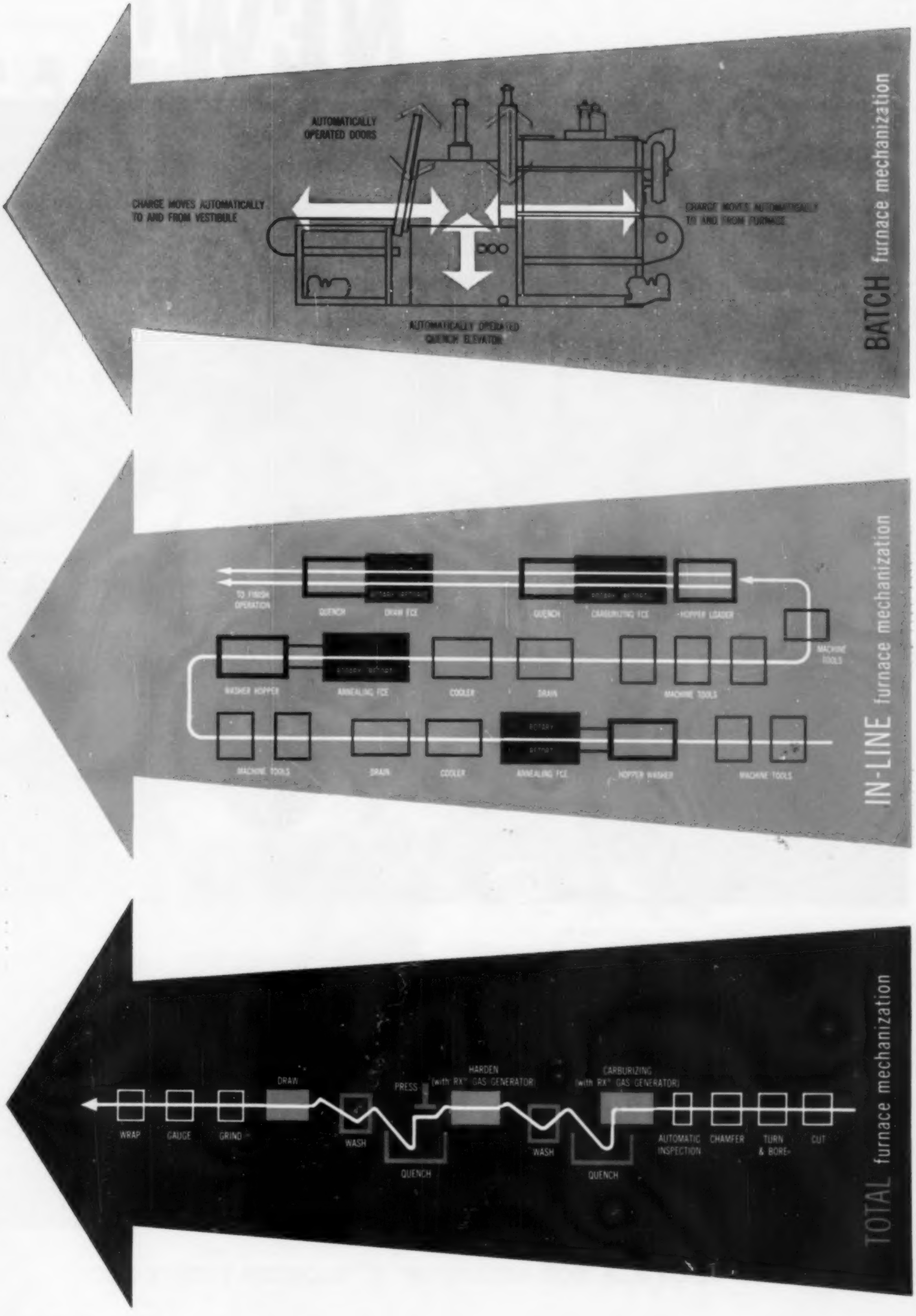
May the Good Lord bless and keep you,
Whether near or far away.
May there be a silver lining back of every cloud you see.
May your troubles all be small ones and your fortunes ten times ten.
May the good Lord bless and keep you 'till we meet again!

I now declare the 2nd W.M.C. adjourned!

Cordially,

Bill

W. H. Eisenman, *Secretary*
American Society for Metals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DRAW
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MACHINE TOOLS
DRAW
COOLER
ANNEALING FCE
HOPPER WASHER
MACHINE TOOLS
TOTAL furnace mechanization
DRAW
PRESS
HARDEN (with RX® GAS GENERATOR)
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NEW!...

▲ At W-K-M Division of A-C-F Industries, Inc., Houston, Texas, Gulfcut Heavy Duty Soluble Oil is being used on turret lathes for threading, boring, facing, turning, and grooving operations. This Gulf customer says: "We get an excellent finish, long tool life with Gulfcut Heavy Duty Soluble Oil."

Erich Brenner, Foreman at W-K-M, informs Jeff Bolling, Gulf Sales Engineer, about the excellent results obtained with Gulfcut Heavy Duty Soluble Oil. ▶

typical large drill bit

Surface metal is cut away to shape drill point and spiral flutes — core is exposed to wear, structural loads

Point and cutting lips are critical to drill performance. If alloy has any weakness at center, poor cutting or broken drill will result. Mel-Trol eliminates this trouble by insuring uniform strength and toughness from surface core. Never before have commercially available alloys been so completely free of segregation, porosity and centerline weakness.

MEL-TROL ...solves a major metalworking problem-poor centerline quality in alloys

The more surface metal you cut away from an alloy steel bar, the more important uniform core quality becomes. The drill illustration above shows you why.

In alloy steels made by conventional steelmaking process, segregation, porosity or other inhomogeneities are often found along the centerline. Result: the core metal lacks the toughness of the rest of the bar, even though it may show no detectable variation.

To alleviate this major cause of poor tool quality, poor tool life and excessive rejects, Carpenter metallurgists developed the Mel-Trol process. Now, for the first time, alloys with complete uniformity from surface to centerline are being made in quantity.

The Mel-Trol process produces freedom from segregation, porosity and centerline weakness through a system of quality controls which play a part in every phase of the entire steelmaking process. Equipment developed specifically for Carpenter is used together with the most modern standard quality control tools. Every piece of equipment is used to its highest accuracy—nothing less.

Mel-Trol alloys are now available at Carpenter mill-branch warehouses. Ask about them the next time a Carpenter representative calls on you. He'll show you how you can join the growing number of companies who are finding Mel-Trol alloys the answer to a host of metalworking problems.

Carpenter STEEL

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Pioneering in improved specialty steels through continuing research

Repeatedly heated to 1830°F...

Repeatedly cooled to quench temperature...

Inconel alloy stack-type trays look "good-as-new" at 2000-hour mark

These lightweight Wiretex-made fixtures also push treating costs down 20% in same period

These pictures make it clear.

After 2000 hours of pit-type heat-treating service, these Inconel* nickel-chromium alloy trays fabricated by Wiretex for Fenn Mfg. Co., Newington, Conn., manufacturers of rolling mills and swagers, are practically undamaged.

No serious attack from high heat. From thermal shock. From furnace atmospheres. From oxidation. From heavy loading. From quenching or degreasing media.

No serious effect, either, from the tempering, and – 120°F deep-freeze operations through which these same trays must often go.

Strength, fabricability of Inconel alloy opens way to new operating economies

Wiretex Mfg. Co., Inc., Bridgeport, Conn., has used the excellent strength and fabricability of wrought Inconel alloy to design into these trays features that cut Fenn's heat-treating costs some 20%. These include:

(1) A reduction in fixture weight that cuts heating time approximately 25%.

(2) An increase in allowable work load per tray over former trays of 30%.

(3) Improved stacking and lifting configurations speed materials handling.

The use of easily weldable Inconel alloy also improves repairability of the equipment, extends its life expectancy. There are two good ways to get the word about Inconel alloy fixtures: Your fabricator is one. The other is to write for the Inco bulletin, "Keeping Costs Down When Temperatures Go Up." *Registered trademark

The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

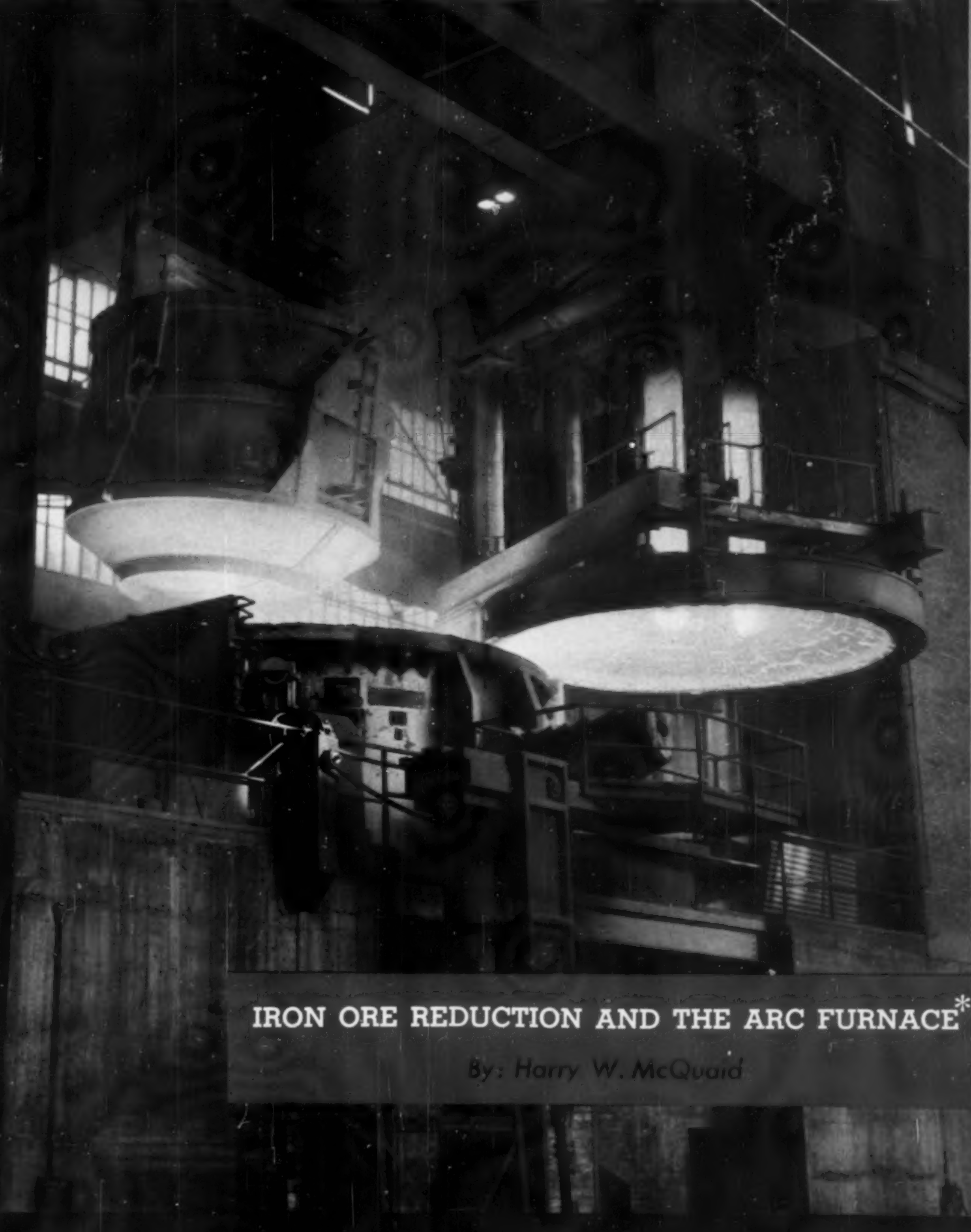
"This shows you tray design. Walls are solid Inconel alloy rolled and welded. Removable Inconel alloy grid and woven screen rest on shoulder."

Inconel *...for long life at high temperatures*

INCO Nickel Alloys

DECEMBER 1957
Vol. 4 No. 4

NATIONAL CARBON COMPANY'S CARBON AND GRAPHITE NEWS



IRON ORE REDUCTION AND THE ARC FURNACE*

By: Harry W. McQuaid

IRON ORE REDUCTION AND

Over five hundred years of development brought the modern blast furnace to its present size and present quality of product. Today, the blast furnace has reached its zenith in the fully integrated steel plant. Teamed with ore handling equipment and the coke oven, the blast furnace supplies steel melting furnaces with a charge of hot, fluid, molten iron.

THE ARC FURNACE*

BY **HARRY W. McQUAID**

Consulting Metallurgical Engineer

* Based on a paper delivered by H. W. McQuaid at the 1957 Annual Convention—Association of Iron and Steel Engineers.

Blast Furnace Limitations

Burning coke with preheated air for combustion, the blast furnace converts commercial iron oxide (ore) and an alkaline reagent (limestone) to a molten state. The reduction of iron ore by carbon monoxide which is formed by partial combustion of coke, is a relatively slow process. In addition, the process is badly handicapped by the need to melt high percentages of flux plus the melting of ore and nonmetallics under high reducing conditions.

One principal improvement which might be made in blast furnace hot metal or pig iron, would be to drop the carbon (not below 2%) and eliminate silicon and sulphur. Such a charge would be ideal for both the open hearth and the electric furnace, especially for heats which must pass cleanliness tests and be employed as an alloy steel base. Some will note that unless low sulphur fuels are used on the open hearth and in the scrap, the low sulphur, low silicon hot metal or pig is probably a wasted refinement.

However, it is my experience that a low sulphur and low silicon hot metal or pig addition, when associated with a good carbon boil, is helpful in obtaining good looking billet etches, particularly in heats on the hot side and not too fully deoxidized.

Due to the increasing height and diameter of the modern blast furnace, the need arises for an improvement in coke quality and uniformity, ore preparation, and burden uniformity. Because of this, the future development of the blast furnace seems to be becoming more uncertain every day. As a matter of fact, it has apparently reached the stage of its existence where every possible commercial step will be taken to replace it.

Objectives Of Direct Reduction

The first objective of direct reduction is to obtain relatively low cost equipment for producing commercial grades of iron to compete with cold pig iron or good grade scrap. And, to produce iron that can be somewhat independent of coke—at least high grade, special quality coke. Many processes for the direct reduction of iron ore to replace scrap or blast furnace pig iron have been proposed in the past forty years. Though many of the attempts were unsuccessful, they have been of value in indicating what should be avoided for a successful direct reduction process.

In recent years, the advances made in ore concentration and the removal of gangue material prior to reduction have greatly improved the chances of direct reduction success. For example: the preparation of finely divided concentrated ore has improved the reaction rate and the thoroughness of reduction. Also, final mixing of the highly concentrated, finely divided form with a reagent selected for oxygen removal, has been developed to assure complete reduction.

Electric Furnace Melt Shops

Every hot metal and pig iron user in this country and Europe is patiently waiting for the time when iron ore can be directly reduced (in low cost equipment) to either liquid or solid iron. Actually the first to be attracted by such direct reduction equipment should be the electric furnace melt shop. The use of the direct reduction process to stabilize the price of scrap will be of the greatest interest to every electric furnace high tonnage operator in the country. While liquid iron would be of advantage in replacing scrap in the electric furnace, any form of solid iron would also be desirable. The electric furnace can use iron in any form (hot or cold) as its basic charge material.

It will be especially desirable to electric furnace melt shops if small yet efficient direct iron oxide reduction plants can be built at a relatively small investment cost and operated in parts of the country where high grade coking coal is difficult to obtain.

Hydrogen As A Reducing Agent

Hydrogen may play an increasingly important part in the reduction of iron ore. It is entirely possible as the development in the field takes place, hydrogen requirement on a commercial basis will be below 25,000 cubic feet per ton and might approach 20,000. It is easy to arrive at an estimate of the direct reduction costs for the hydrogen reduced product, which now finds its initial tonnage application in the special low sulphur electric furnace charge. Its principal competition would be extra high grade scrap. A study of costs available indicates the production of a high carbon, low sulphur charge such as "H-Iron" should be carefully considered by every electric furnace melting plant producing low sulphur special steel. This is one means of insuring some stability in the cost of the charge which goes into the melting furnaces. It is appealing in areas of high scrap costs and in areas of low natural gas costs. This indicates a field in Pittsburgh (high scrap costs) and Texas (low fuel costs).

Studies have shown that not only "H-Iron" but other hydrogen reduction operations can be reduced to a practice which will produce a melting furnace charge for replacing #1 and #2 heavy melting scrap in almost any furnace. On this basis alone, hydrogen reduced iron ore has a reasonably bright future as long as steel scrap keeps its sensitive relation to supply and demand. It should have the best wishes and interest of every electric melting furnace operator throughout the country.

Carbon As A Reducing Agent

In considering the direct reduction of iron ore, let us remember that if the product which results from such a process is above 95% in iron content, low in carbon and silicon, we wind up with a high iron product with a high melting point. This would be primarily competitive with scrap and not with hot metal or pig iron. In fact, directly reduced iron ore in the form of a very low carbon, low silicon iron of high purity will not fit at all in the open hearth economy. It would fit much better into the electric melting picture where its economic position would be directly compared with available scrap. Both electric furnaces and open hearths would benefit if a relatively high carbon, low silicon iron were available preferably as hot metal or as a cold pig charge.

If another means of reducing iron oxide (ore) for the open hearth or Bessemer is developed, it will be economically necessary to use carbon or carbon monoxide as the basic reducing agent. This is necessary to produce iron in the liquid form and to control the silicon to best suit the melting furnace requirement. The logical approach to such an end would be to melt the highly concentrated iron ore under the best fuel and oxidation conditions of oxygen enriched blast, high temperature combustion. And, to treat the largest possible surface of molten, superheated ore with incandescent carbon and superheated flux. This appears to be a problem for the best combustion engineers and furnace builders. The reduction of iron ore (oxide) by treating it in the molten state with carbon is fast becoming an important means of obtaining iron from ore. It promises someday to become a strong rival of the blast furnace in areas where high grade coke is difficult to obtain.

Hence, no matter what method of iron ore reduction we study—carbon, carbon monoxide or hydrogen, three principal factors in our efforts to improve the process are important: First, the intimacy of the mixture; Second, the continual removal of the reaction products; Third, the accurate control of the temperature.

Submerged Arc Ore Reduction

Under certain conditions where transportation charges, power and other costs are favorable (as they are in many locations), the direct reduction of iron ore by smelting in the submerged arc furnace is more economical than the blast furnace. This is true if we have to engineer and build a blast furnace at present day costs. Here, the high cost of building a new blast furnace involves carrying (fixed) charges which make the submerged arc furnace look especially attractive.

The deoxidation of molten and superheated iron ore with carbon in an electric arc furnace occurs with tremendous rapidity if the carbon-iron ore mixture is intimate and a violent reaction can be permitted. The rate of reaction can be regulated to suit the operator by controlling the temperature and the rate of carbon feed into the really active bath. The problem becomes one of two distinct phases: First, to produce highly fluid, concentrated iron ore. Second, to control closely the reaction of this iron ore concentrate with intimately mixed, finely divided carbon. So far the most successful practice of the ore reduction method has been in Norway, Sweden, Italy and other parts of Europe as well as South America.

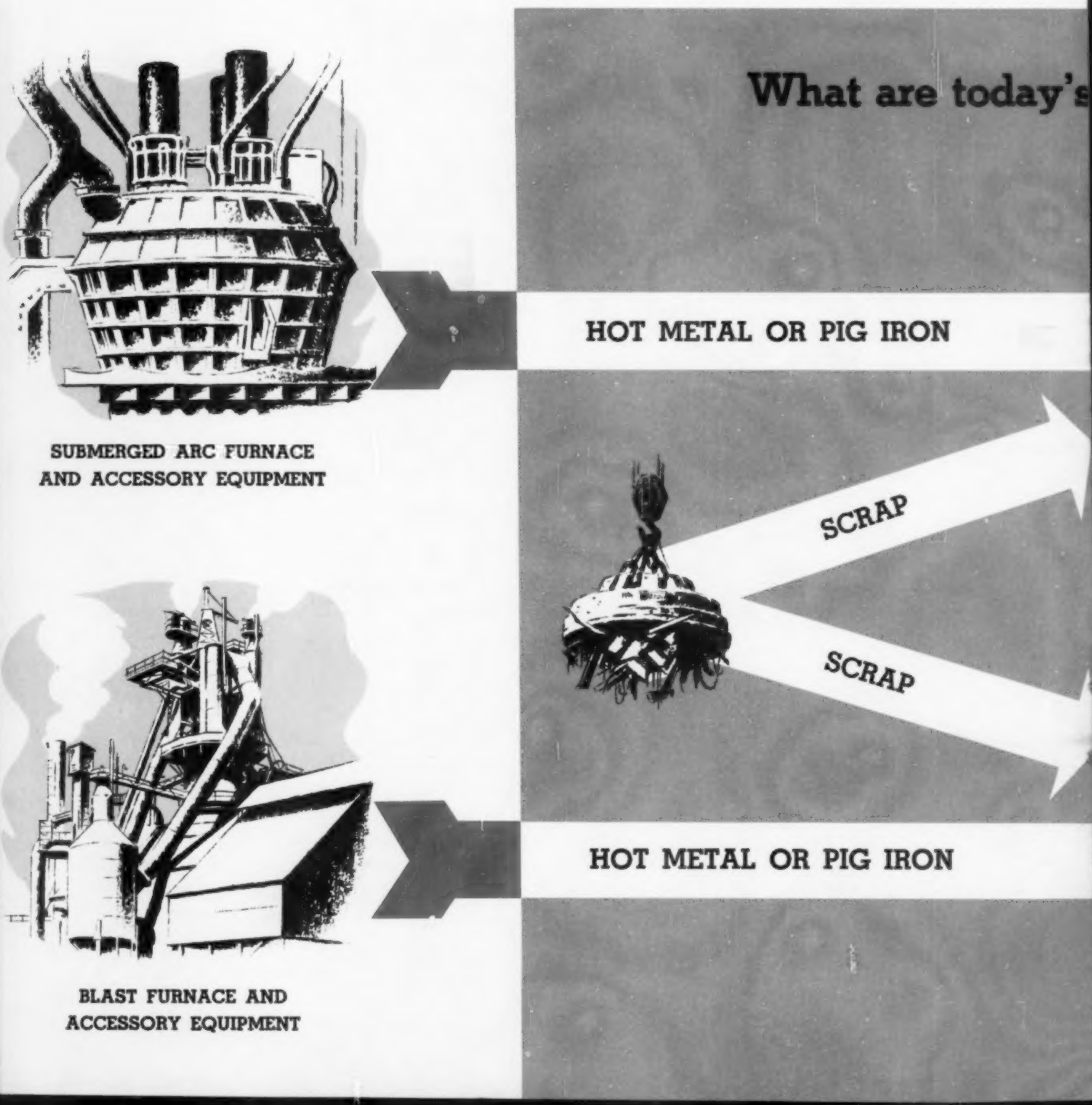
Typical applications in Europe employ the modern electric arc furnace using carbon electrodes which melt and superheat the ore in contact with crushed low grade anthracite. The problem of melting a crushed iron ore and coal mixture in a modern arc furnace is not difficult so long as the ore is molten and the temperature is high enough. The carbon will react rapidly with the oxygen in the fluid ore and reduction is only a matter of minutes. The submerged arc electric furnace is accepted as probably the best means of developing direct reduction of molten iron ore with carbon.

Assuming that a mixture of highly liquid iron ore and carbon is made available, it should be fairly simple to eliminate the oxygen, thereby assuring a liquid charge metal for the open hearth or electric steel furnace. For this reason, the production of hot metal or pig iron from ore might soon become common throughout non-integrated, properly located foundries and steel plants.

Over ten years ago, the first attempts in this field indicated as low as 1300 KW hours per net ton of iron produced when highly concentrated magnetite ore was reduced with carbon in an electric furnace. Now, I am told 1100 KW hours will be closer to the real power requirement per net ton of iron produced in this country. This makes production of electric furnace hot metal or pig iron a very important economic development in the steel industry.

A leading electric furnace steel producer in combination with a large nonferrous metal producer, has now reduced to practice an iron oxide reduction process. This process provides a melting stock for use in steel mill furnaces supplying any desired grade of steel.

It is early to express any opinion on the actual merits of this direct form of ore reduction, but all considerations (including the experience abroad) indicate it is in good hands. The publicity which is expected shortly will, I am certain, show that a new tonnage method of reducing iron oxide to metallic iron with carbon has been developed. It will rapidly be taken over by those electric furnace operators to whom it is especially suited.

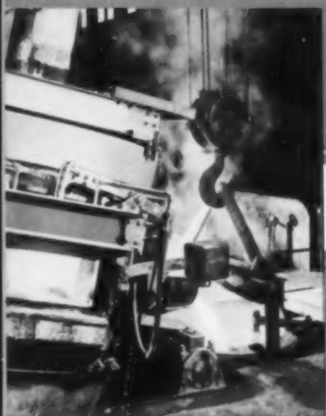


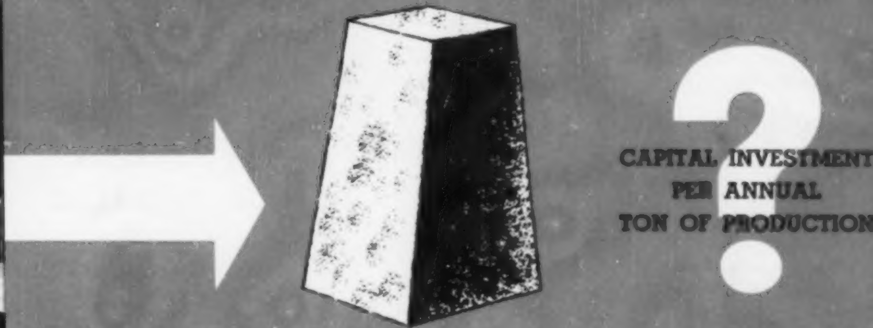
Those interested in this subject should read the article "Electric Furnace Pig Iron" by Dr. E. C. Wright of the University of Alabama, published in the July 1957 Carbon and Graphite News. Also of interest is the chapter on Electric Pig-Iron Smelting by A. G. E. Robiette in his book entitled "Electric Melting and Smelting Practice". These sources offer basic information on the subject of ore reduction by the electric melting furnace.

Arc Furnaces In The Integrated Plant

Because of the high investment cost reached in the installation of high tonnage modern open hearth furnaces and accessory equipment, today's thinking has favored large electric arc furnaces. This is particularly true where the present fully integrated open hearth battery is at the full limit of existing hot metal production equipment. Here the addition of one or two large high powered electric arc furnaces can average more than twenty-five tons per hour of semi-killed merchant bar ingots from available scrap. It is interesting when we examine the investment per annual ton, and in this case, the open hearth looks anything but attractive. In some fully integrated

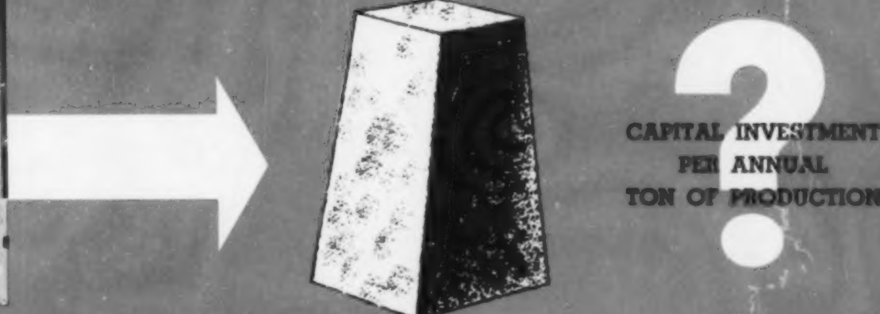
:omparative costs per annual ton of steel production?





Electric Furnace

In some fully integrated plants, the present investment of the blast furnace and open hearth combination will cause steel plant executives to give thought to the submerged arc electric for smelting and electric furnaces for refining.



)pen Hearth Furnace

plants, the present investment of the blast furnace and open hearth combination will cause steel plant executives to give thought to the submerged arc electric for smelting and electric furnaces for refining. This is evident since the apparent discovery that savings in power will pay for almost any degree of ore concentration attempted.

Conclusion

It seems apparent that several approaches to the direct reduction of iron oxide as a steel melting furnace charge are not far away. As in all important developments, once the industry-wide conditions indicate the new iron product to be economically desirable, it will be developed. The time is not far away when even the relatively small, more distant steel producer will become well integrated by installing a low cost iron ore reduction unit in one corner of the plant. It will provide him with the most economical charge for his melting furnace and the battle will be on between the scrap supplier and the ore salesman. The larger tonnage steel plant using hot metal or cold pig iron will find it wise to investigate the new iron ore melting practice combined with its reduction by carbon to a high carbon, low silicon, low sulphur hot metal.

Whatever develops, it is apparent that the reduction of iron ore to produce either a molten product similar to blast furnace hot metal, or a solid product similar to low carbon heavy melt steel scrap, has now reached the stage where it is being reduced to practice. It will require many months to determine what method or methods will be adopted by the industry. But, when the development is finally adopted throughout the steel industry, we will no doubt wonder why it took so long.

It is interesting to speculate on the heartbreaking rejections met by some men in trying to introduce an outstanding new development to an industry. Especially has this been true in the past with the steel industry where the direct reduction of iron ore was easy to postpone for another year. But today, continually increasing customers' pressure for improved quality in every product and the increasing evidence of better quality, cost and delivery in your competitors' product, has resulted in the highest possible pressure for development of new and better production equipment. Because of the high investment cost of blast furnace open hearth combinations, present equipment will be kept in operation just as long as it is commercially possible. This makes it difficult for the engineer to answer the sales department's request for increased capacity. The electric arc furnace will try to meet this demand.

The answer must be a development in low cost iron ore reduction practice to provide the steel melting furnace and foundry cupola with a material which will reduce in cost, and stabilize the price of its main charge. It is evident that such a development is now in the making and all that is needed for success is an industry wide concentration on the problem and a pressing demand for results.

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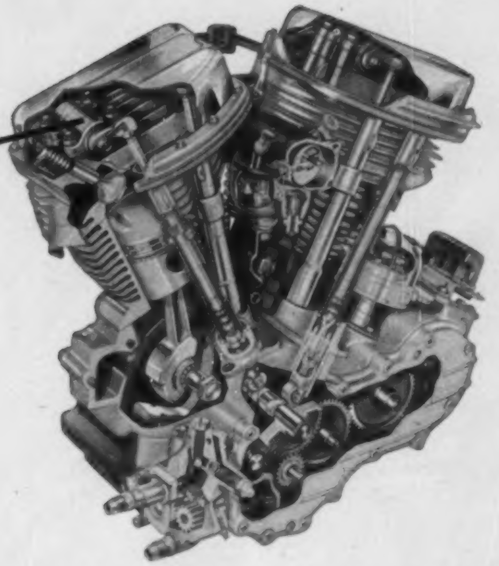
SHARON STEEL CORPORATION *Sharon, Pennsylvania*

DISTRICT SALES OFFICES: Chicago, Cincinnati, Cleveland, Dayton, Detroit, Grand Rapids, Indianapolis, Los Angeles, Milwaukee, New York, Philadelphia, Rochester, San Francisco, Sharon, Seattle, Montreal, Que., Toronto, Ont.



HARLEY-DAVIDSON MOTOR CO.

Harley-Davidson motorcycles (made in Milwaukee, Wisconsin) have, since 1903, enjoyed a world famous reputation for economical, reliable transportation. These versatile machines are ideally suited for pleasure, for commercial or business use, as well as the grueling demands of law enforcement work. Harley-Davidsons boast a dependable engine . . . one which can roll up an astounding mileage record with little or no care. The painstaking selection of every engine component is one important reason for this reliability. The new twin-cylinder Harley-Davidson 74 OHV employs Mueller Brass Co. bronze alloy forgings in the form of rocker-arm bearing caps. Subjected to violent temperature changes, fast starts and stops and road shock, Mueller forgings are proving again and again that they have the ability necessary to withstand almost any punishment . . . and still provide unfailing service.

JACOBSEN MFG. CO.

Jacobsen Mfg. Co., Racine, Wisconsin, was among the first to produce a practical power mower for home use. That was more than 35 years ago! Today, Jacobsen power-mower dependability is evident itself in more than a dozen gleaming new models such as the popular Pacer, Lawn Queen, Manor and others. One of the most reliable components in the always dependable Jacobsen hi-torque engine is a Mueller Brass Co. connecting rod forged from special bronze alloy. Jacobsen mowers with Mueller-forged connecting rods are called upon by some commercial users to operate as much as 8 hours daily, 6 days a week . . . perhaps as much as 2000 hours a year. In searing summer temperatures, thru hours of constant operation, the high uniform strength of Mueller bronze forgings constantly withstands pounding and vibration with the same conspicuous success as in its many other applications.

Why not investigate these specialized alloys for your own products. We welcome your inquiries. Our engineering staff will be happy to make specific recommendations. Both on the proper alloy and the best method of fabrication to meet your needs . . . exactly. Our engineering manuals show many, many examples of how American manufacturers have used these alloys to great advantage.

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- Mueller Brass Co. Forgings Engineering Manual H-58565 ☐
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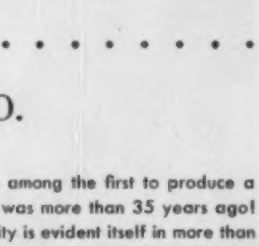
- "600" Series Bearing Alloys Engineering Manual FM-3000 ☐
- Copper Base Alloys in Rod Form Engineering Manual FM-3010 ☐



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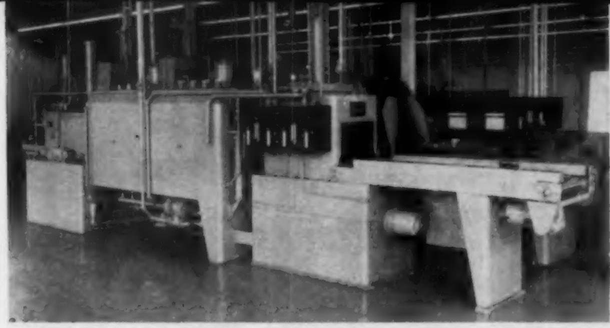
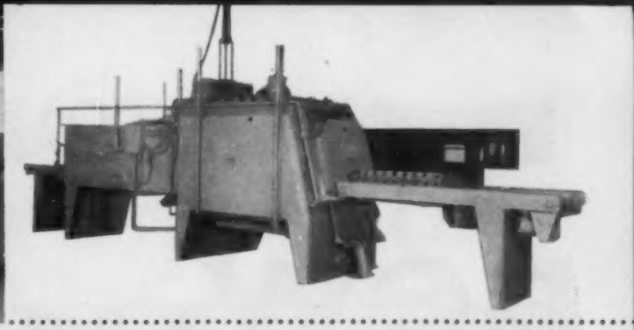
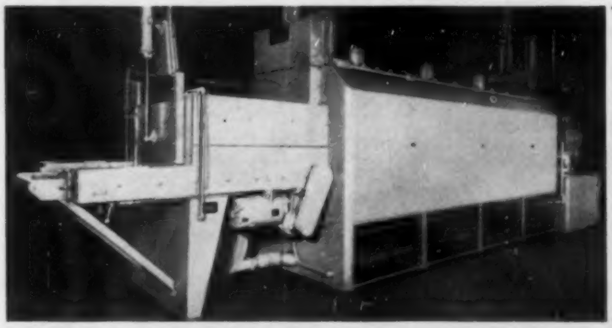
PORT HURON 28, MICHIGAN



100% forced convection "straight-through" controlled atmosphere heat treating unit. Typical applications: carburizing, light case carbo-nitriding, neutral hardening, and marquenching. Available in 8 standard sizes from 150 to 2500 lbs. per hr. Ideally suited for automatic production lines.



This "straight-through" furnace is for applications calling for controlled atmosphere cooling. These units have two-zone, water-jacketed, cooling chambers with forced convection cooling. Available in sizes to 1000 lbs. per hr. Heating is 100% forced convection with alloyed ceramic heating tubes.



Ipsen standard "pusher" furnace . . . multi-zone, controlled atmosphere furnace for carburizing, carbo-nitriding, and general heat treating. Has atmosphere purge vestibule sealed to charging end . . . oil quench enclosure at discharge end. Capacities from 400 to 4000 lbs. per hr.

Ipsen gas-fired washer for use with Ipsen automatic heat treating units. Drying available—rinsing optional. Available in four sizes—automatic or semi-automatic operation.

Designed for bright drawing and similar applications, this atmosphere tempering unit is available for capacities from 200 to 2000 lbs. per hr.

Ipsen OFFERS A COMPLETE LINE OF STANDARD CONTROLLED ATMOSPHERE FURNACES AND ACCESSORIES

Endothermic controlled atmosphere generator. Ipsen also makes exothermic generators; ammonia dissociators. 11 sizes—250 to 2500 cu. ft. per hr. Gas-fired or electric.

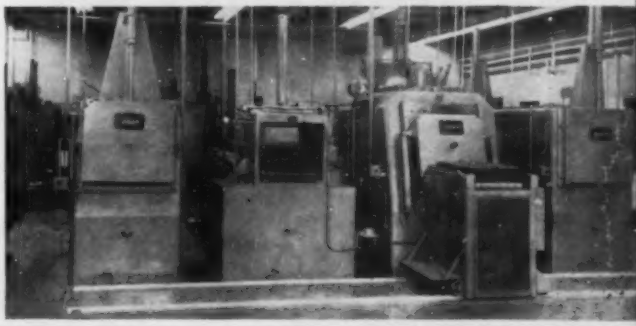
Ipsen "Carbotronik" (left) automatically controls carbon potential of furnace atmosphere. "Dewtronik" (right) automatically controls atmosphere dew point.

Ipsen now offers America's most complete line of controlled atmosphere heat treating equipment . . . in *standard* designs, sizes, and types. Your furnace can be built immediately . . . no waiting while it's being engineered, because it's already engineered!

Standard Ipsen controlled atmosphere furnaces are available in more than 70 different sizes and types . . . from 4000 lbs. per hour controlled atmosphere units . . . to small laboratory furnaces.

Ipsen also offers a full line of standard, already engineered, semi-automatic loading and unloading equipment . . . dew point and carbon potential controllers . . . atmosphere generators . . . washers and related equipment.

Pictured on this page are a few of the many standard units offered by Ipsen . . . descriptive literature available upon request.



Semi-automatic loading and unloading equipment is available for single Ipsen heat treating units. With wheels and suitable track, single loaders and unloaders may serve a battery of furnaces.

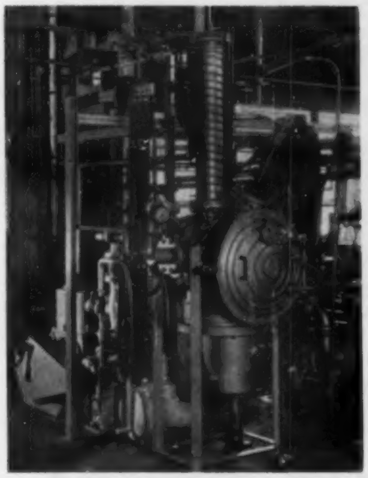
AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • 723 SOUTH MAIN STREET • ROCKFORD, ILLINOIS

APPLICATION and EQUIPMENT new products

Vacuum Melting

A new vacuum-arc skull melting furnace capable of pouring 8 lb. of titanium or 14 lb. of steel has been announced by NRC Equipment Corp. A choice of arc mechanisms is available for permanent or consumable electrode operation. The basic unit



consists of a 30-in. diameter, 33-in. long horizontal vacuum chamber with sight ports and ports for the connection of permanent electrode mechanism, consumable electrode tower and cold or chill mold assemblies. The power supply consists of two silicon rectifiers of 1250 amp. each, at 40 volts.

For further information circle No. 1649 on literature request card, page 48-B.

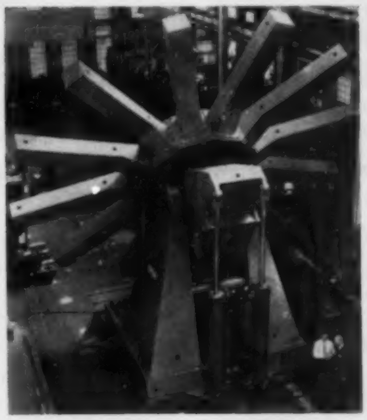
Salt Bath Control

A new impulse monitor which automatically provides for shutting down an electric salt bath heat treating furnace in the event of control instrument or relay failure has been announced by the Ajax Electric Co. The impulse monitor responds to the duration of the energy input feeding the furnace. It is set manually. Timing devices offer two ranges, either from 0 to 240 min. or from ½ to 30 hr. Should the power input to the furnace continue longer than the time selected, the monitor first endeavors to shut off the power. Failing in this because of fused contact tips or similar trouble, it then signals an alarm over telephone lines, lights, bells or other protective devices.

For further information circle No. 1650 on literature request card, page 48-B.

Welding Positioner

Pandjiris Weldment Co. has announced a positioner weighing 100 tons and having an over-all height of 20 ft. 10 in. Its table, looking somewhat like a rimless spoked wheel, has a diameter of 33 ft. By means of a 2000 lb. hydraulic system, the table can be tilted to any angle up to 60 deg. The machine is equipped with



two electric motors which turn the table—a 2 hp. motor for slow forward and reverse speeds and a 7½ hp. motor for rapid traverse.

For further information circle No. 1651 on literature request card, page 48-B.

Rolling Titanium

General Plate Div. of Metals & Controls Corp. has announced that production quantities of commercially pure titanium and some titanium alloys are being rolled to foil gage and annealed. Profile rolled shapes resembling an "L" have also been produced. All types of commercially pure titanium are rolled to a minimum thickness of 0.001 in.; Beta alloys, type B-120 VCA, rolled to 0.002 in. minimum; Alpha-Beta alloys, 6AL-4V and others, to minimum thicknesses depending on the alloy of 0.003 to 0.001 in. All can be annealed.

For further information circle No. 1652 on literature request card, page 48-B.

Abrasive Wheel

A new abrasive wheel composed of thousands of narrow finger-like abrasive strips has been announced by Merit Products, Inc. The strips of abrasive flex to fit over and around

changing contours. The wheel is primarily useful in polishing, deburring and removal of surface flaws on all metals. Sizes now offered include diameters of 14 and 16 in. with widths from 3 to 60 in. Selection of grits ranges from fine to coarse.

For further information circle No. 1653 on literature request card, page 48-B.

Cleaning Machine

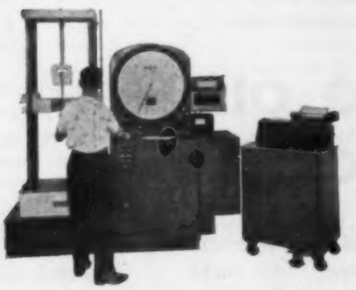
Automatic cylinder head cleaning by a gyro-vertical Aja-Lif cleaning machine combining vertical and rotary agitation of the work has been announced by Magnus Chemical Co. Heads are rolled on the cleaning machine platform from the plant

roller conveyor and are held in position by an adjustable hold-down device. The platform is lowered into the cleaning solution where it immediately starts its cycle of vertical agitation. The rotating device is then started causing the carrier platform and heads to revolve during the fast up and down vertical agitation. Upon completion of the preset cleaning cycle, the platform rises to the top of the tank where it rotates a few additional turns to drain all interior recesses. The machine is designed for optional agitation of the work below the liquid with a 3 to 5 in. stroke, at approximately 160 up and down motions per minute; or a 6 to 10 in. stroke at 60 up and down motions per minute; or a 25 to 30 in. stroke which raises and lowers the platform in and out of the solution on each stroke.

For further information circle No. 1654 on literature request card, page 48-B.

Testing Machine

Test data is printed automatically by an electric typewriter used in conjunction with the new Electomatic testing machine announced by the Tinius Olsen Testing Machine Co. As set, the data printer will record yield strength by the desired percentage of offset, ultimate strength and an identifying test number without operator attention. Electronic signals



to operate the printing control mechanism are generated both by the extensometer affixed to the specimen, and the Selectorange indicating system. The former supplies data on the amount of strain or specimen extension under load, while the latter gives the load applied to the specimen at any instant.

For further information circle No. 1655 on literature request card, page 48-B.

High-Temperature Furnace

A furnace which operates at 3300° F. and 3000 psig. has been announced by Vacuum Specialties Co. It incorporates a split graphite electrical heating element which was originally designed for vacuum service applications at less than one-millionth of an

atmosphere total pressure. This element has been operated at temperatures up to 4400° F. under vacuum. Static and dynamic pressure seals are made with "O" rings. The furnace is instrumented to hold ±1° F.

For further information circle No. 1656 on literature request card, page 48-B.

Tinning Powder

A new tinning compound in powder form for tinning all metals prior to babbitting has been announced by American Solder & Flux Co. This tinning compound forms a chemical bond with cast iron, steel and all metals used for bearings. When the babbitt metal is poured, it will amalgamate with the tinned surface. The result is a permanent bond between the tinned surface and the base metal and between the babbitt metal and the tinned surface.

For further information circle No. 1657 on literature request card, page 48-B.

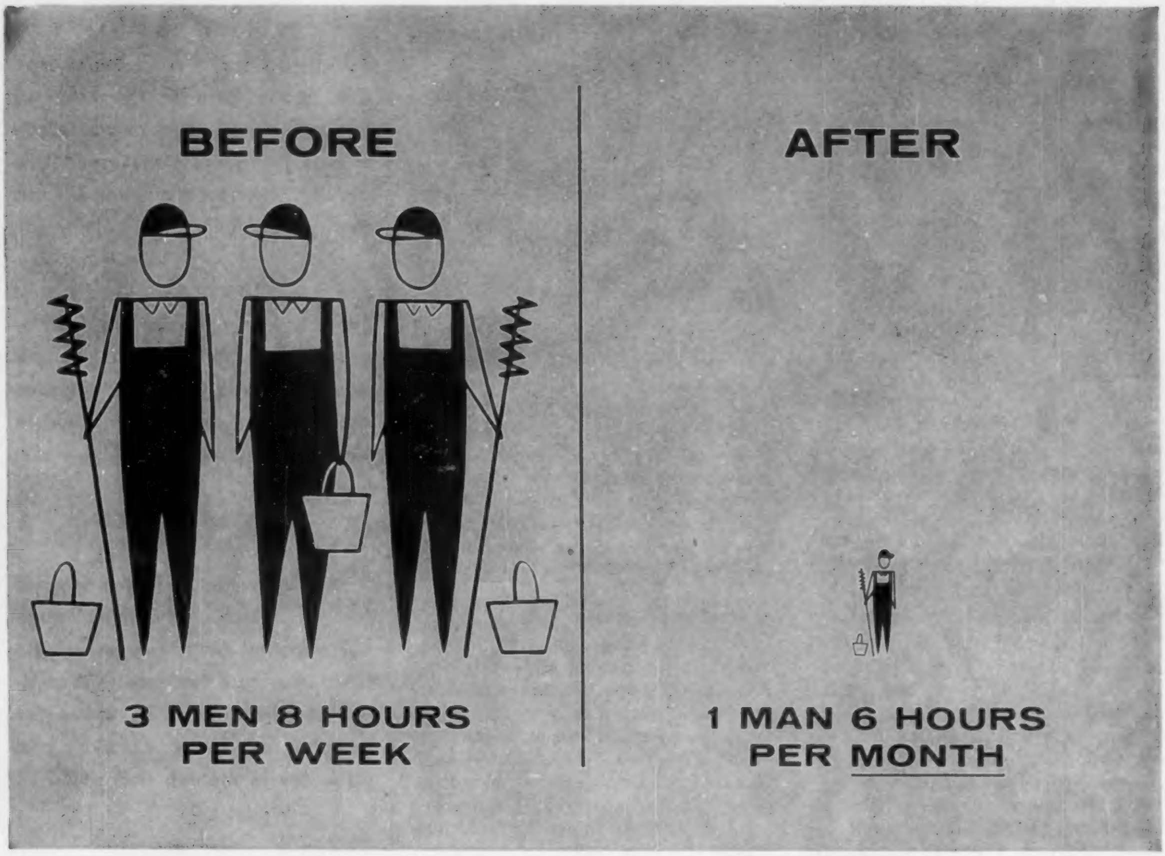
Salt Bath Pots

Custom-made plate pots in Inconel, Incoloy or Type 330 alloys have been announced by Wiretex Mfg. Co. Designed for salt bath heat treating applications when neutral or cyanide salts are used, they are constructed to withstand temperature ranges from 1500 to 2100° F. They are fabricated in any plate thickness with ¼ in. considered standard. Inside diameters come in 12, 14, 16, 18, 20 and 24 in. sizes, with depths to any dimension.

For further information circle No. 1658 on literature request card, page 48-B.

Flaw Detector

A new material for aqueous phase magnetic particle inspection of metals has been announced by Harry Miller Corp. It is nonflammable, odorless and self-cleaning. The speci-



A switch to Sun Quenching Oil Light resulted in this dramatic reduction in cooler-maintenance man-hours in a major automotive plant.

SWITCH TO SUN QUENCHING OIL LIGHT CUTS COOLER MAINTENANCE BY 94%

After switching to Sun Quenching Oil Light, a leading auto manufacturer reported a *94% reduction in cooler maintenance.* No heavy sludge deposit had formed on cooler coils after 18 months of continuous use. It took *fewer* men *far less time* to clean coolers.

Reason: Sun Quenching Oil Light has natural detergency and solvent action that *keeps cooling systems clean for long periods.*

It's Versatile. Sun Quenching Oil Light can be used in any type of quenching-oil system. It has uniform quenching properties and low drag-out.

It's Economical. Sun Quenching Oil Light can save you money two ways . . . in low initial cost and in reduced maintenance.

For Full Information, call your Sun representative or write to SUN OIL COMPANY, Philadelphia 3, Pa. Dept. MP-12.

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fied mixture is one part Immunol 438 to 17 parts water, which mixture suspends uniformly either fluorescent or nonfluorescent paste.
For further information circle No. 1659 on literature request card, page 48-B.

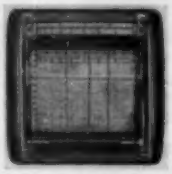
Powder Metallurgy

A new hydraulic pressure system which controls pressing of powdered metal and ceramic parts has been added to its mechanical compacting presses according to an announcement of Haller, Inc. It is a side mounted unit consisting of an oil-

filled accumulator which is charged to 100 psi. with nitrogen, a sandwich-type check valve and a relief valve. A pressure gage indicates in pounds per square inch the pressure used in the cylinder at each stroke of the press. Adjustments in pressure may be made while the press is running.
For further information circle No. 1660 on literature request card, page 48-B.

Recorder

The Foxboro Co. has announced that six new features have been added to the standard panel-type Consotrol instruments. The Models 53 and 54 will accommodate three pens so that three measurements can be monitored on the same chart. A Model 54 recording control station can be tilt-mounted, for use



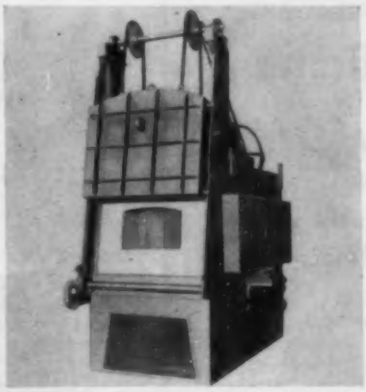
in console units. Batch Stabilog control permits the use of reset action on batch processes without wind up or overshooting at the start of an operating cycle. Patented Auto-Selector action provides a smooth transfer of reset control selectively for any number of related variables. A new chart tear-off bar and automatic-manual switch handle are standard with each instrument.
For further information circle No. 1661 on literature request card, page 48-B.

Filler Rod

Ampco Metal, Inc., has announced a new all-purpose, low-fuming, manganese-bronze filler rod. Produced from virgin metals to insure maximum usability, Ampco Braz #2 may be used in brazing and braze-welding steel, cast iron, malleable iron, copper and copper-base alloys in addition to overlaying bearings and other wear and corrosion resistant surfaces. It produces joints with strength up to 60,000 psi. Overlay deposit hardness is 80 to 110 BHN (500 kg. load).
For further information circle No. 1662 on literature request card, page 48-B.

Electric Furnaces

The L & L Mfg. Co. has announced a new line of high-temperature furnaces. The furnaces were designed for operation to 3000° F. for flash heats in oxidizing or neutral atmospheres, to 2850° F. for continuous operation in oxidizing or neutral atmospheres, and to 2500° F. for operation continuously in reducing atmospheres. The pictured model has a usable firing chamber 18 in. wide by 12 in. high by 160 in. long. Insulation is multi-layered and the pri-



mary insulating brick can operate at 3200° F. Interior of the furnace is coated with alumina. The elements are of silicon-carbide with low watt density. Door design is of power lift type with a safety latch. Rating is 65 kva.
For further information circle No. 1663 on literature request card, page 48-B.

Thickness Measurements

A new X-ray gage which measures the thinness of strips of film or foil moving at speeds up to 6000 fpm. has been announced by the Sheffield Corp. Low intensity X-ray pulses,

Try this on your next assembly job: apply Grafo AC-360

(colloidal graphite dispersion)

to all bearings and rubbing surfaces in your machines, engines, sub-assemblies

Here's what it will do:

- create slip surfaces
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Oven Model shown at right is only one in this size and price range with full multiple directed forced convection.

Q.S.

Model No.	Heating Chamber Dimensions Usable	Temperatures	Price
QS	28¾"W x 28"D x 21¾"H	225°	$110.50
QL	28¾"W x 28"D x 21¾"H	325°	$117.50
QM	26½"W x 19"H x 22"D	550°	$333.50
QH	24"W x 16"H x 21"D	800°	$595.00
QR	24"W x 16"H x 21"D	1000°	$740.00

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DYNATROL FURNACE LINE
to 2000° & 2300° F

PRICE FROM **$90.00** UP

OVER 40 STANDARD MODELS AVAILABLE

L&L MANUFACTURING CO.
Chester 77, Pa.

NEW, Portable Indicator

MINIMITE
Has 23½ Inch Double Scale

Small Size Extremely small and compact, the "MiniMite" Portable Potentiometer Indicator weighs under four lbs. and measures only 4" x 5" x 6".

Scale Range Despite its small size the "MiniMite" has a 23½ inch scale. Standard double scale range is 0—1800° F. for Iron-Constantan and 0—2400° F. for Chromel-Alumel. Other scale ranges are also available. Measuring accuracy is ¼% of scale range.

Dual Application The "MiniMite" can measure temperature directly when connected to a thermocouple, or check other potentiometer or millivoltmeter-type instruments when used as a comparison instrument.

Write for Bulletin 64-H.

Thermo Electric Co. Inc.
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NEW...

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emitted 60 to 600 times per sec., permit instantaneous measurement at point of gaging of foils made of aluminum, steel, copper and brass, plastic films and sheet or bar stock as thin as 0.0002 in. A reading can be taken every $\frac{1}{3}$ in. on strip moving at 1000 fpm. as the instrument emits 600 X-ray pulses per sec.
For further information circle No. 1664 on literature request card, page 48-B.

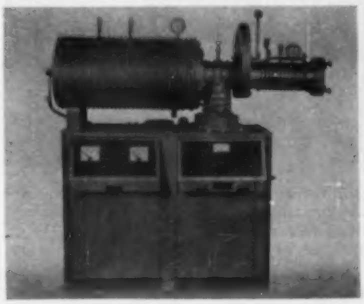
Grinder-Mixer

An instrument designed to mix or grind samples and particularly standards for emission and X-ray spectrographic analysis has been announced

by Spex Industries. For mixing powders, plastic balls are provided, together with plastic vials or jars. Up to 100 ml. of material may be blended in 5 min. or less. For grinding, either a hardened tool steel vial or a high-alumina ceramic vial is offered. Up to 15 ml. of ore, slag, ceramic material or brittle metal, such as platinum sponge, tungsten and molybdenum may be ground to –300 mesh. Samples are swung through all three planes at high speed. The entire mechanism is enclosed in a sheet metal housing which acts as a safety shield.
For further information circle No. 1665 on literature request card, page 48-B.

Vacuum Furnace

High Vacuum Equipment Corp. has announced a vacuum annealing furnace which converts to a melting furnace. It is intended for laboratory or light production. The F1212-2A is a double-pumped muffle-type furnace with a hot zone of 6 in. i.d.



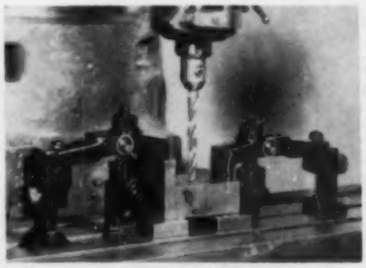
by 12 in. long. It is capable of operating continuously at 2150° F. or intermittently at 2200° F. at a pressure of 1×10^{4} mm. Hg. or less, It can be converted to a melting furnace by substituting a spherical chamber with a resistance heated furnace containing a crucible suitable for melting 12 lb. of steel to 3600° F.
For further information circle No. 1666 on literature request card, page 48-B.

Adhesive

Eastman Chemical Products has announced a new liquid adhesive which is rapid setting and has high strength. One drop of this colorless liquid used to join two 2-in. steel rods end-to-end will support 200 lb. of pull within 5 min. If the adhesive is permitted to set for 48 hrs., it will support 15,000 lb. It has been used to join combinations of steel, aluminum, copper, magnesium, bronze and brass as well as plastics, wood and other materials. Adhesive power is destroyed by prolonged exposure to high humidity and temperatures above 212° F.
For further information circle No. 1667 on literature request card, page 48-B.

Machine Tool Clamp

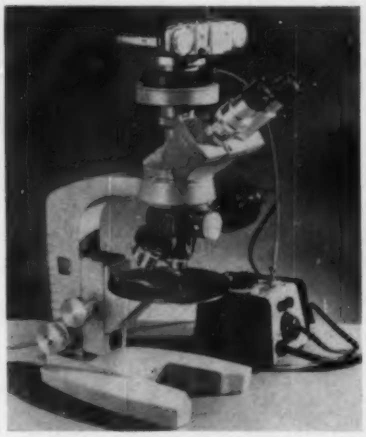
A new machine tool clamp assembly has been announced by Hi-Lo Products Co. It has clamping ranges of $\frac{7}{8}$ to $2\frac{1}{4}$ in. and $2\frac{3}{8}$ to $4\frac{7}{8}$ in.



Models are available with "T" or stud bolt subassemblies which are interchangeable and with patented $\frac{1}{4}$ turn serration lock feature.
For further information circle No. 1668 on literature request card, page 48-B.

Microscope

A new series of metallurgical microscopes has been announced by the American Optical Co. An outstanding feature of the new microscope is a microglide circular stage that permits specimen positioning under the objective in any horizontal direction. Four interchangeable, rotatable (to 360 deg.), inclined bodies are available—monocular, binocular, trinocular and special monocular photographic body. A 35 mm. camera can be mounted on the trinocular or



photographic monocular body. A vertical illuminator provides a 6.5 volt, 2.75 amp. light source which is controllable by aperture and field diaphragms.

For further information circle No. 1669 on literature request card, page 48-B.

Burners

Designed for small industrial and commercial heat applications and for piloting larger gas burners, a new series of miniature burners have been announced by Maxon Premix Burner Co. They have a capacity range of 50,000 to 150,000 Btu. per hour. Firing can be at a continuous fixed rate or automatic on-off control can

be used, and any clean fuel gas can be handled. Burners are blower-mixing and produce an air-gas mixture of predetermined, adjustable ratio, and deliver it under pressure to a nozzle for ignition.

For further information circle No. 1670 on literature request card, page 48-B.

Vacuum Furnace

A new high vacuum furnace, designed for continuous operation at 3900° F. at a vacuum of 0.01 to 0.05 microns, has been developed by Vacuum Furnace Div. of Richard D. Brew and Co. The new furnace features a tantalum heating element which is clamped on two sides to prevent sag. It also has a sight tube, through which optical pyrometer readings can be made without raising the cover of the heater shell assembly. The furnace, power supply and 6 in. high vacuum pump, plus 30 cfm. mechanical backing pump, are contained in one cabinet. Furnace chamber is 18 in. i.d. by 18 in. high.

For further information circle No. 1671 on literature request card, page 48-B.

Finishing Machine

A new flat finisher for wet abrasive belt grinding, polishing and deburring of flat work up to 6 in. wide by 6 in. high has been announced by Hammond Machinery Builders, Inc. An endless conveyor belt with variable speed control allows continuous production. The FF-6 is available with a single head or as a multiple head machine. The abrasive belts are carried by two rolls—a powered contact roll and a tracking idler. Vertical adjustment is manually controlled and tensioning on the idler roll is maintained by adjustable air pressure. An electro-

magnetic platen is used to hold material on the conveyor belt for positive drive under the contact roll. Hold down rollers, mounted ahead and behind each contact roll, are used when nonmagnetic material is to be processed. Spray, mist, fog, and splash are trapped by the metal enclosures around each head to insure a clean, dry work area.

For further information circle No. 1672 on literature request card, page 48-B.

Projector

A new microprojector featuring a vertical principle of design has been announced by the George Scherr Co. Work is laid on the horizontal stage. An inclined screen reproduces the enlarged image. Custom

made coated lenses and achromatic condenser lenses give 10 to 100× magnification.
For further information circle No. 1673 on literature request card, page 48-B.

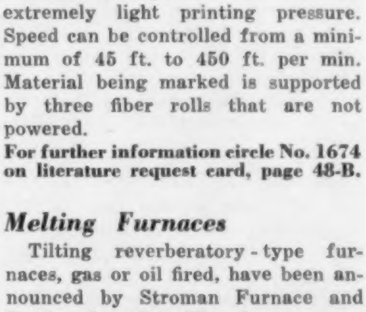
Tube Marking

The Pannier Corp. has announced a small offset wire bar and tube printer designed to handle material

from ⅛ to 4 in. o.d. without changing guide wheels. The unit will print a continuous message set on 24 in. offset printing wheel in type sizes from 1/16 to 1 in. A ½ hp., 3 phase, variable speed motor chain drives, with a floating idler sprocket, only the marking head to forward material through the unit with an extremely light printing pressure. Speed can be controlled from a minimum of 45 ft. to 450 ft. per min. Material being marked is supported by three fiber rolls that are not powered.
For further information circle No. 1674 on literature request card, page 48-B.

Melting Furnaces

Tilting reverberatory-type furnaces, gas or oil fired, have been announced by Stroman Furnace and Engineering Co. The furnaces are



949 tons of tin product rolled

in 8 hours—on USS Quality Forged Rolls

The man in the small picture is Charles D. Kelly, Superintendent of the cold reduction and sheet finishing department at U. S. Steel's giant Fairless Works. He was completing his 20th year when a crew on the 5-stand cold reduction mill rolled out an impressive 949 tons of tin product in a single 8-hour shift.

The mill was equipped with USS Quality Forged and hardened rolls, as might be expected. But you should know that no U. S. Steel mill is obligated to buy rolls from the company if competitive rolls will give better performance. Here is the heart of the story: based on careful long-range performance figures, the USS forged rolls are equal to or better than any other on the market.

As a major steel producer, U. S. Steel has the opportunity to test the quality of its rolls. Even further, U. S. Steel buys rolls from other manufacturers—for an evaluation of our product. Over and over again, records have shown that USS Quality Forged Rolls have improved wear resistance, and a high degree of cleanliness.

When buying most custom-made steel products, the customer specifies the quality, type and chemistry of the steel, as well as heat-treating procedures and other manufacturing methods. Not so with rolls. With the exception of physical dimensions, surface finish and hardness level, rolls are sold strictly on the basis of performance. Do you keep a careful record of your roll performance? If you do, you may well find yourself ordering USS Quality Forging rolls *all* the time.

Please address inquiries or requests for our free 32-page Forging booklet to United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.

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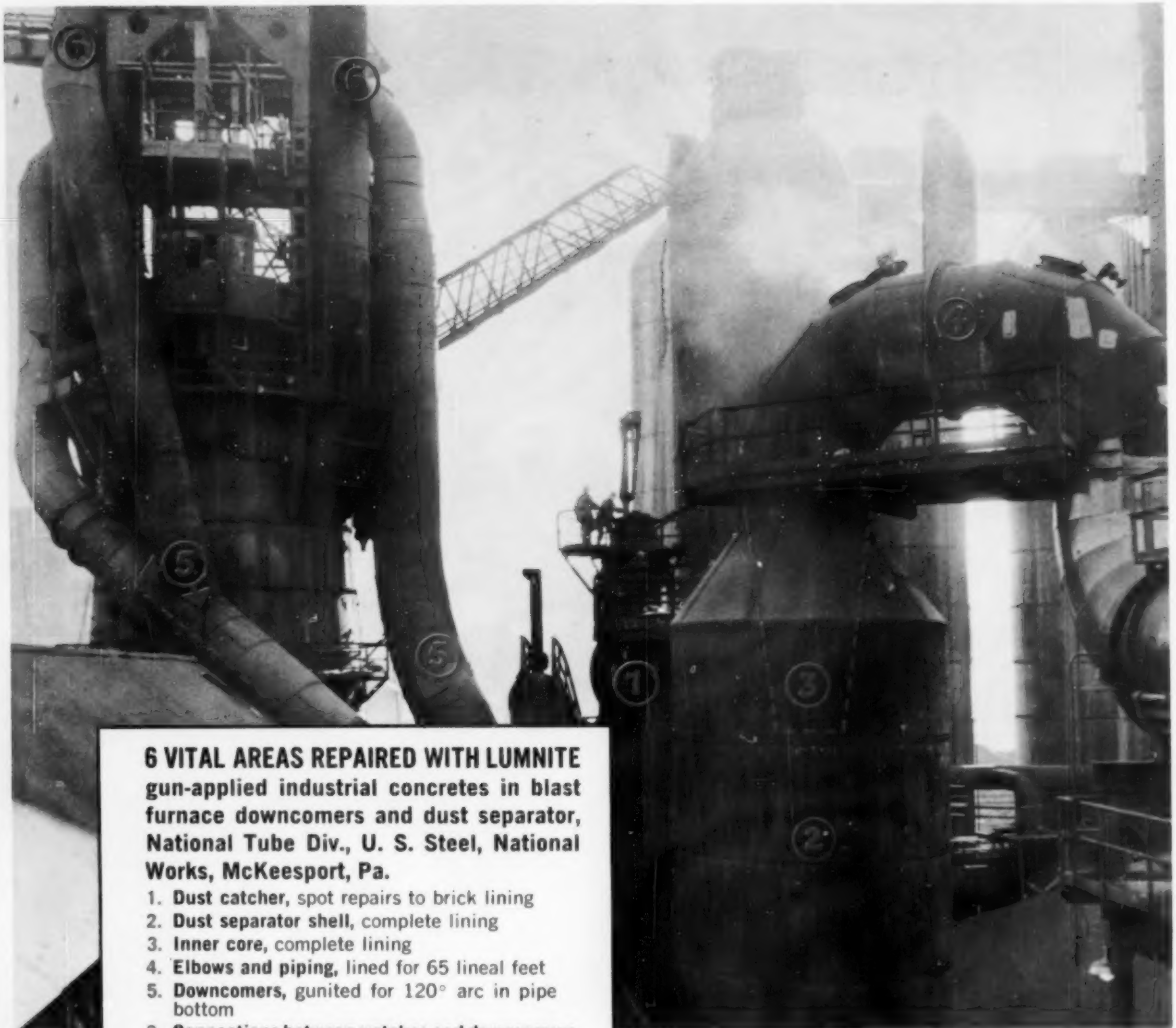
heavy machinery parts . . . carbon, alloy, stainless
forged steel rolls and back-up roll sleeves
electrical and water wheel shafts
specialty forgings of all types

USS



6 VITAL AREAS REPAIRED WITH LUMNITE gun-applied industrial concretes in blast furnace downcomers and dust separator, National Tube Div., U. S. Steel, National Works, McKeesport, Pa.

1. **Dust catcher,** spot repairs to brick lining
2. **Dust separator shell,** complete lining
3. **Inner core,** complete lining
4. **Elbows and piping,** lined for 65 lineal feet
5. **Downcomers,** gunited for 120° arc in pipe bottom
6. **Connections between uptakes and downcomers,** spot-repaired (two other connections gunited not shown)

Atlas LUMNITE* industrial concretes protect blast furnace "hot" spots

- Industrial concrete linings made with Lumnite cement will resist abrasion, corrosion and heat.
- Placement is fast and easy, by guniting, casting or troweling—service strength is reached in less than 24 hours.
- Outage is reduced to a minimum.

For maximum convenience, use Lumnite-made castables. These are packaged mixtures, ready for use. Just add water, mix and place. Made and distributed by leading manufacturers of refractories.

Write for your copy of the new "Lumnite Mortar Manual," describing gun-applied linings: Universal Atlas, 100 Park Avenue, New York 17, N. Y.

UNIVERSAL ATLAS CEMENTS

*"LUMNITE" is the registered trademark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

L-158

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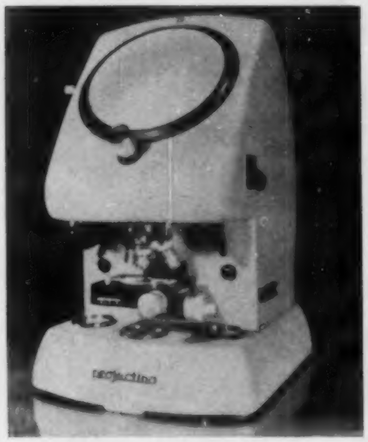
made in 1000, 1700, 2500 and 3000 lb. holding capacities with hourly melt rates closely paralleling the rated capacities. Removable spring loaded bung-arches which form the entire roof simplify maintenance and relining.
For further information circle No. 1675 on literature request card, page 48-B.

Inspection

Alfred Hofmann & Co. has announced a combined microscope, projector, comparator and camera. It is portable. By fitting an adapter to the observation face, any image previously projected on the screen in



the magnification range of 7 to 2000× may be photo recorded. Built-in illuminators permit microscopy and projection in transmitted bright and dark field as well as surface bright and dark field. Stationary, mechanical and high precision mechanical stages are provided.
For further information circle No. 1676 on literature request card, page 48-B.

Wire Flattening

Stanat Mfg. Co. has announced the development of a new tandem wire flattening mill. The machine consists

of two mill stands, each equipped with 8 in. diameter by 5 in. wide rolls, faced with cemented tungsten carbide rings. A welded structural steel base carries the mill stands, two dancer roll mechanisms and a traversing recoiler. The mill is capable of producing strip in thicknesses ranging from 0.010 in. up and in widths to ⅝ in.
For further information circle No. 1677 on literature request card, page 48-B.

Rust Removal

Heatbath Corp. has announced a new alkaline derusting compound. It will remove rust, scale, paint, enamel, lacquer and oil from ferrous metal without attacking the base metal. Derustal can be used to replace acid pickling operations. It is a free flowing powder and is used 1 to 3 lb. per gal. of water at a temperature of 180° F. to boiling. Time of immersion will be from a few minutes to a half hour, depending upon the amount and kind of rust, scale, paint to be removed. Only mild steel equipment is required.
For further information circle No. 1678 on literature request card, page 48-B.

Diffractometer

A new X-ray diffractometer has been announced by the Instruments Div., Philips Electronics, Inc. Three components comprise the assembly: a basic X-ray generator and tube; wide-range goniometer with detector; electronic circuit panel with strip-chart recorder. The diffractometer is designed to operate on 200 to 240 volts, a.c., 50 or 60 cycles, with full wave rectification and facilities for visual indication of rectifier

functioning. X-ray tube current is provided with stepless controls to give up to 60 Kvp. and 50 Ma. indicated on visible meters. A stabilizer is built into the unit to keep X-ray tube current constant.
For further information circle No. 1679 on literature request card, page 48-B.

Tough 2½" diameter mandrel at Rc 44 on 1150 ton brass extrusion press. Scovill Manufacturing Co.

Mandrel of HALCOMB 218 retains toughness and hardness at hot work temperatures...

This mandrel is made of Halcomb 218—a tough, air-hardening hot work steel. Halcomb 218 is suitable for tools like this which require a higher degree of toughness at moderately elevated temperatures than is obtainable with the tungsten types of hot work steels. And Halcomb 218 *retains both* its hardness and strength at these temperatures.

For example, at a hardness of Rc 44, Halcomb 218's Charpy Impact Strength is 33 ft-lbs at 500F. And it will retain this hardness after 1 hour, after 10 hours and even after 100 hours at temperatures up to 900F.

Properties like these cut tooling costs. The mandrel shown above is good for 1200 pushes, for example, and even then all it needs, usually, is repolishing before being used again.

Halcomb 218 is particularly useful for all hot work operations on which drastic coolants are used. It even resists breaking very successfully when water cooled in operation. If these sound like advantages you can use, call your local Crucible representative for more complete data. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

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Crucible Steel Company of America

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Large Stocks of One-Piece Elements. You get quick deliveries of Norton "Hot Rods" — on short notice. Also, most popular sizes of these CRYSTOLON heating elements — like the sizes shown in this section of the Worcester stockroom — are now made in the new, one-piece construction — with no welds. This assures greater strength and uniform straightness throughout each rod.

Greatly Increased Strength. Ever since they were first produced "Hot Rods" have been endorsed by users for outlasting other non-metallic heating elements up to 3 to 1. Today, the new one-piece rod, made in most popular sizes — and soon available in all sizes — is twice as strong in standard cross-bending tests.

One-piece "HOT RODS" now ready for immediate delivery...famous for long life and economy

CRYSTOLON heating elements bring you extra advantages for better performance and bigger savings*

Straighter Than Ever. Throughout the entire length of a one-piece, non-welded "Hot Rod" there isn't the slightest bulge in the surface. So, when you insert them into the openings of your furnace or kiln you can be sure there'll be no binding due to uneven diameters.

Scientifically Safe Packaging protects "Hot Rods" even more thoroughly than delicate household glassware or china. They're packed shockproof to reach you unbroken.

"Hot Rods" are a typical Norton ℞ — an expertly engineered prescription for greater efficiency and economy in electric furnaces and kilns. Made of self-bonded silicon carbide, each rod has a central hot zone and cold ends. Most popular sizes are non-welded and interchangeable with your present rods.

You save in element costs because you use far less "Hot Rods." Also, their more uniform heating quality, due to their slow, evenly matched rate of resistance increase, helps you protect product quality and maintain a smooth production flow. For further facts on "Hot Rod" advantages send for booklet *Norton Heating Elements*, NORTON COMPANY, Refractories Division, 333 New Bond St., Worcester 6, Massachusetts.

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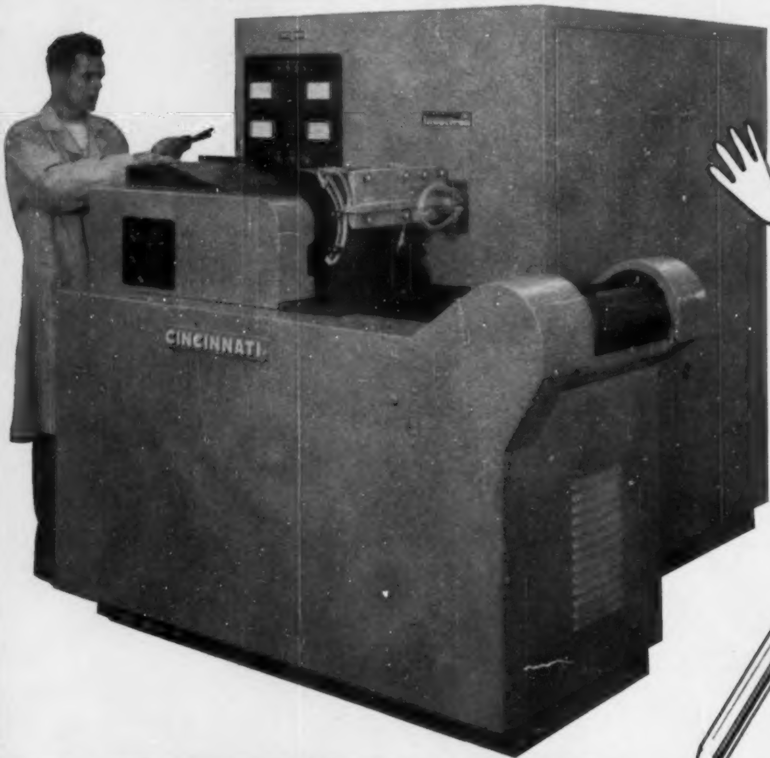
Coated Abrasives • Sharpening Stones
Pressure-Sensitive Tapes

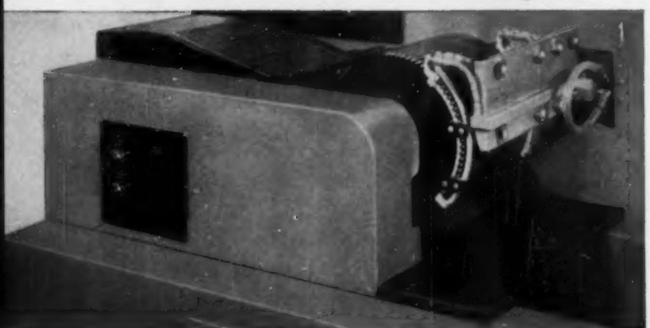
new Cincinnati Inductron hardens push rods at 1-per-second rate!



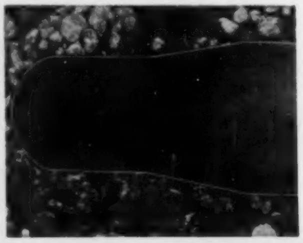
Induction hardening both ends of automotive engine push rods is accomplished at a rate of 3600 parts per hour by this new 15-kw Cincinnati Inductron®, operating at 1.2 megacycle frequency. Except for hand loading the parts into a chute, operation of the unit is automatic. Rods are gravity-fed into a "ferris wheel" which carries the parts through the work coils. Heated parts drop into the oil quench bath at one second intervals. Quenched parts are carried from the tank to tote bins by a conveyor.

This installation is one of many possible Cincinnati Inductron adaptations for the high speed selective hardening of small parts, thin walled and other parts requiring shallow case and narrow transition zone. In addition, the Inductron is equally well suited for low production operations on a wide range of work, using easy-to-form work coils. These high frequency machines are built in water or air cooled 15-kw and 30-kw, and water cooled 50-kw capacities.

You'll profit by taking your selective surface hardening problems to Cincinnati—builders of *both induction and flame hardening machines.* Call in a Process Machinery Division field engineer. He is ideally equipped to evaluate your needs and give you unbiased recommendations as to the most economical equipment for your work.



Close-up view of fixture, which accommodates two sizes of push rods, 5/16" x 10" and 5/16" x 11½". Part material is SAE 1065 steel. Controls include heat and fixture start-stop push-buttons and speed control knob for varying the rate of fixture rotation.



Micrograph showing push rod tip hardness pattern. Hardness achieved is 58-62 Rockwell C, with .050" minimum case depth. Hardened area extends 9/32" back from rod tips.

CINCINNATI

flamatic and inductron

hardening machines

PROCESS MACHINERY DIVISION

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CINCINNATI 9, OHIO, U. S. A.

APPLICATION and EQUIPMENT new literature

1681. Abrasion Tester
Bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Taber Instrument Corp.*

1682. Abrasives
New catalog on various types of shot and grit abrasives. SAE specifications and types of cleaning and peening methods. *Cleveland Metal Abrasive*

1683. Air Washers
Bulletin No. 256 on acid-proof air washers for ventilation systems. Construction and accessories. *Automotive Rubber*

1684. Alloy Cast Iron
64-page bulletin A-71 on engineering properties and applications of Ni-Resist. Corrosion data compared with gray cast iron. *International Nickel Co.*

1685. Alloy Castings
22-page bulletin 2041 on heat and corrosion resistant castings. *Blaw-Knox*

1686. Alloy Steel
Comparative tables of SAE and AISI standard steels and tentative standard steels. *Babcock & Wilcox*

1687. Alloy Steel
32-page book on abrasion resisting steel. Properties, fabricating characteristics, uses. *U. S. Steel*

1688. Alloy Steel
Data book on the selection of the proper alloy steel grades for each manufacturer's needs. *Wheelock, Lovejoy*

1689. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrication, welding. *Great Lakes Steel*

1690. Aluminum
24-page data book on high-strength aluminum-zinc-magnesium-chromium-titanium alloy. Properties, aging, corrosion. *Frontier Bronze*

1691. Aluminum
12-page booklet on extruded shapes, tube and pipe, coiled sheet, forgings and properties of aluminum alloys. *Revere*

1692. Aluminum Alloy
Bulletin 103 on high strength aluminum alloy which ages at room temperature. *Federated Metals Div.*

1693. Aluminum Bronze
8-page booklet on study that led to development of one-piece, nickel-aluminum bronze ship propeller. *International Nickel*

1694. Aluminum Die Casting
Data on radiant aluminum die casting furnaces. *J. A. Kozma Co.*

1695. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

1696. Ammonia
New 69-page data book on anhydrous ammonia and ammonia liquor. Chemical and physical properties, specifications, analytical procedures, bibliography. *Nitrogen Div.*

1697. Ammonia Dissociator
12-page bulletin B-53 on ammonia dissociation equipment. Sizes and capacities, testing unit, cost chart. *Drever Co.*

1698. Annealing
Bulletin SC-146 on cycle annealing in atmosphere and direct-fired furnaces. Steels annealed and hardnesses obtained. *Surface Combustion*

1699. Arc Welding
60-page booklet on how to get better welds. Metals and electrodes, proper procedures, types of joints, typical positions, welding symbols. *Hobart Bros.*

1700. Atmosphere Control
8-page bulletin on furnaces, atmosphere equipment, controls for bright annealing, hardening and tempering, batch annealing, age hardening and carburizing. *Surface Combustion Corp.*

1701. Bending Machines
New 30-page book on how to bend, equipment, shapes and how each is made. *O'Neil-Irwin Mfg. Co.*

1702. Beryllium
25-page reprint No. 24 from Rare Metals Handbook gives properties, fabrication, applications of beryllium. Bibliography. *Brush Beryllium Co.*

1703. Bimetal Applications
44-page booklet, "Successful Applications of Thermostatic Bimetal", contains uses, formulas, calculations. *W. M. Chace*

1704. Blackening Copper
Bulletin of operating instructions for blackening and coloring copper and copper alloys. *Enthone*

1705. Blast Cleaning
New 24-page bulletin 100C on blast cleaning hose machines. Selection and uses. *Pangborn Corp.*

1706. Brazing
16-page reprint on furnace brazing gives advantages of method, design factors and methods of handling assemblies and furnaces for brazing. *Electric Furnace Co.*

1707. Burners
New Buzzer catalog on industrial gas burners and gas furnaces for heat treating carbon and alloy steels. Pot furnaces and melting furnaces. *Charles A. Hones*

1708. Burners
Bulletin 214 on dual-fuel burner for ovens, kilns, driers, forge furnaces, heat treating and malleabilizing furnaces. *North American Mfg.*

1709. Carbides
76-page catalog 56-G of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

1710. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

1711. Carburizing
Data folder on Aerocarb E and W water-soluble compounds for liquid carburizing. Case depth vs time curves. Per cent carbon and nitrogen penetration curves. *American Cyanamid*

1712. Castings
20-page catalog 57 on casting aluminum and magnesium. Patterns, alloys cast. *Wellman Bronze & Aluminum Co.*

1680. Corrosion-Resistant Alloys
Information on four nickel-base alloys—Hastelloy B, C, D and F—is given in this new 104-page edition of Hastelloy Corrosion Resistant Alloys. The booklet describes chemical compositions, physical, mechanical, and high-temperature properties of the alloys. Comparative resistance to over 250 corrosives

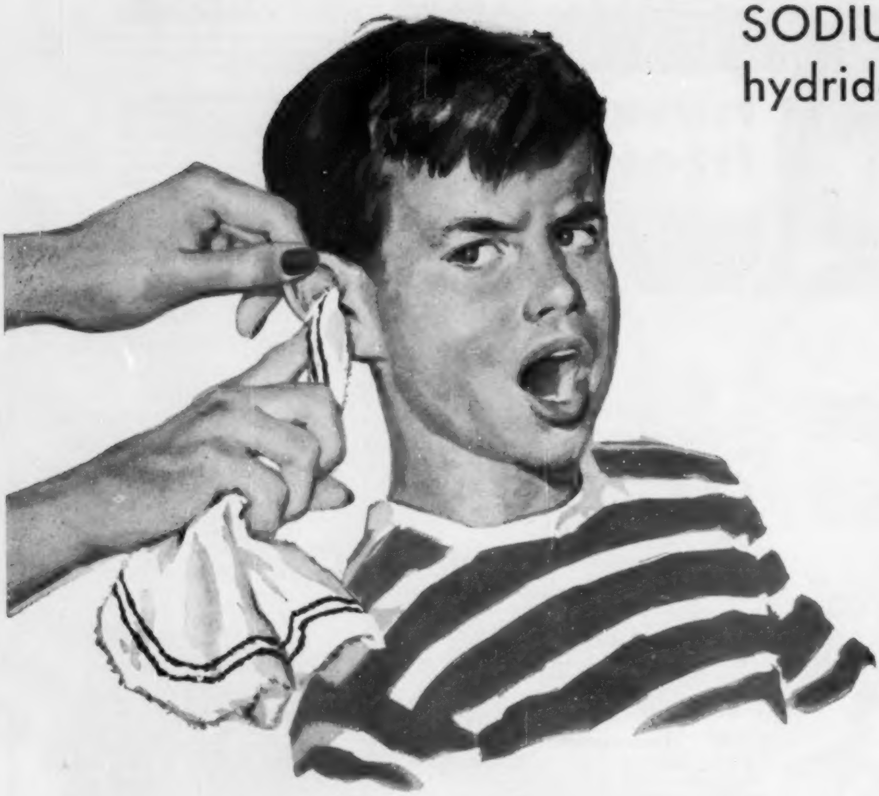
in the chemical, petroleum, paper and pulp, pharmaceutical and metalworking industries is presented in tabular form. Laboratory penetration data for some of the common corrosives such as hydrochloric, sulphuric, nitric, phosphoric, acetic and formic acides are included. A separate section describes techniques for forging, cold working, machining, grinding and welding of the alloys. *Haynes Stellite Co.*

1713. Centrifugal Castings
12-page indexed catalog on custom-made centrifugal castings of 70 different alloys. Analysis and properties of heat, corrosion and abrasion resistant alloys, carbon and low alloy steels, nonferrous metals. *Sandusky Foundry and Machine*

1714. Chain
4-page bulletin DH-101 on sling chains. Selection, working loads. *American Chain*

1715. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

1716. Cleaning Compound
Bulletin B-6 on water displacing com-



pound for producing unspotted, dry surfaces. *Apothecaries Hall*

1717. Cold Finished Steel
16-page booklet on 10 grades of cold finished steels. Analysis, machinability, heat treatment, wear resistance. *Jones & Laughlin*

1718. Cold Treatment
4-page bulletin on low-temperature treatment and equipment. *Alpha Electric Refrigeration*

1719. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

1720. Copper Alloys
24-page manual on alloys in rod form. Typical parts. Specifications covering alloys described. *Mueller Brass*

1721. Copper Alloys
16-page publication E-5 on physical properties and applications of high-strength, corrosion-resistant copper alloys. *American Brass Co.*

1722. Corrosion Protection
16-page bulletin on corrosion proof construction materials includes sections on corrosion proof cements, tank linings, protective coatings and others. *Atlas Mineral Products*

1723. Crystallography
Folder on powder cameras, single crystal goniometers. *Jarrell-Ash*

1724. Degreasers
Folder on vapor and solvent degreasers describes equipment and advantages. *Randall Mfg.*

1725. Degreasing
34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

1726. Descaling
24-page book "Handling Metallic Sodium" with special reference to sodium hydride descaling. *U.S. Ind. Chem.*

1727. Descaling
Bulletin on system of descaling stainless, alloy steels and titanium after heat treating. *Kolene Corp.*

1728. Descaling
Bulletin 1184 on descaling salt for desanding and cleaning castings. *Hooker Electrochemical*

1729. Descaling
2-page service bulletin on a powdered acid. Advantages. Where it should be used. *Oakite*

1730. Dew Point Recorder
Bulletin 11-16 on recorder. Specifications and accessories. *Foxboro Co.*

1731. Die Casting
New edition of 32-page pocket-book on zinc die castings. Factors affecting soundness, common defects. *Henning Bros. & Smith*

1732. Die Casting
Illustrated catalog on complete line of die casting machines. *Kux Machine*

1733. Die Sections
12-page bulletin on composite die sections. Steels used, sizes, heat treating data, engineering data, examples. *Composite Forgings, Inc.*

1734. Diffractograph
4-page bulletin on electron diffractograph. Operation, applications, accessories. *New England Scientific Instruments Co.*

1735. Disintegrators
Catalog B-1 on disintegrator which will remove embedded broken tools. Specifications. *Jiffy Disintegrator*

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1736. Drawing Dies
12-page bulletin on turks head, adjustable draw die. Basic types, development of turks head, various types. *Fenn Mfg.*

1737. Ductile Iron
28-page bulletin gives advantages and applications of ductile iron. Properties. *International Nickel Co.*

1738. Electric Furnace
Bulletin 5610 on rocking electric furnace with motor-driven electrodes. Ratings, special features and characteristics. *Detroit Electric Furnace Co.*

1739. Electric Furnaces
Data sheet describes and gives specifications of standard non-metallic resistor furnaces. *Harrop Electric Furnace Div.*

1740. Electric Furnaces
8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

1741. Electric Furnaces
12-page bulletin on box-type electric furnaces for toolroom applications. Performance data for each type. *Westinghouse Electric Corp.*

1742. Electric Furnaces
Folder on electric furnaces with zone control, temperature indication, automatic control. *L & L Mfg. Co.*

1743. Electric Heating
4-page bulletin on electric heating elements for pipe, tube and tank heating. Sizes, temperature control, element life and installation discussed. *Cooley Electric Mfg. Corp.*

1744. Electrodes
Bulletin 810 on removable submerged electrodes. Advantages. *Ajax Electric*

1745. Electrolytic Iron
New 4-page folder on uses and properties of 99.9% pure iron. *Van der Horst*

1746. Electron Microscopy
4-page bulletin on specimen preparation for electron microscopy. *RCA*

1747. Electron Tubes
Folder on tubes for industry, research and other applications. Separate data sheets give description, operating conditions, constant current characteristics. *Machlett Laboratories*

1748. Ferro-Alloys and Metals
104-page book gives data on more than 250 different alloys and metals produced by the company. *Electro Metallurgical*

1749. Finishing
Bulletin on Luster-On 52 conversion coating for zinc. *Chemical Corp.*

1750. Forging
Brochure on Cameron forging process. *Cameron Iron Works*

1751. Forgings
New folder on facilities for production of flat-die forged products. Electronic equipment used. *Smith-Armstrong*

1752. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

1753. Forgings
Series of articles on modern forging methods. *Hill Acme*

1754. Forgings
16-page booklet shows how forgings are made, sizes and tolerances. *McInnes Steel*

1755. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

1756. Furnace
Bulletin T-19A on controlled atmosphere heat treating furnace. *Ipsen*

1757. Furnace
4-page bulletin KM-570 on Karbo-Matic automatic furnace for hardening, carbonitriding or carburizing. Operation. Heating elements. *Pacific Scientific*

1758. Furnace Belts
44-page catalog describes metal belts for quenching, tempering, carburizing and other applications. *Ashworth Bros.*

1759. Furnace Fixtures
16-page catalog on baskets, trays, fixtures and carburizing boxes for heat treating. 66 designs. *Stanwood*

1760. Furnace Loader
Bulletin on loader for heat treat furnaces. *Michigan Crane & Conveyor*

1761. Furnace Supplies
8-page catalog on accessories to melting furnaces including linings, silicon-carbide base blocks, burners, blowers, pots and so on. *Lindberg Engineering*

1762. Furnaces
Folder on recirculating furnaces illustrates and describes 9 models and endothermic gas generator. *Standard Fuel Engineering Co.*

1763. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

1764. Furnaces
Bulletin on radivection furnaces with radiant heat and forced convection. Advantages. *A. F. Holden*

1765. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnaces. *Waltz Furnace*

1766. Furnaces
4-page reprint on high thermal head furnaces for continuous slab heating installation at Atlas Steels, Inc. Cross section view of radiamatic unit. *R-S Furnace*

1767. Furnaces
Data on line of melting, heating and heat treating furnaces for ferrous and nonferrous metals. *Loftus Engineering*

1768. Furnaces
Bulletin on graphite tube furnaces for temperatures to 5000° F. Operating limitations, auxiliary and control equipment. *Harper Electric*

1769. Furnaces
Folder on new sizes, specifications for soft metal reverberatory furnaces. *Eclipse Fuel Engineering*

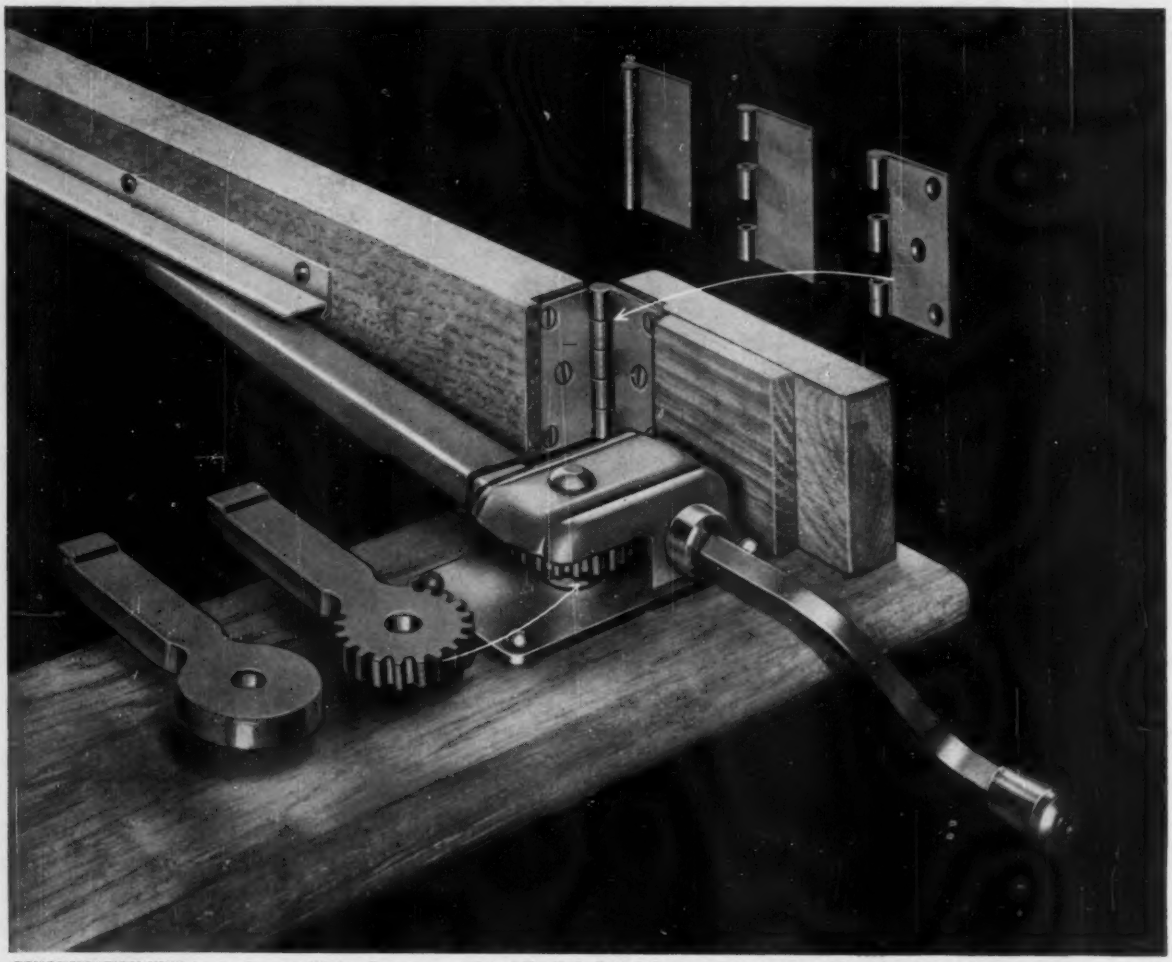
1770. Furnaces
New 36-page book No. 150 on crucible melting furnaces, pot melting furnaces, holding furnaces, die-casting furnaces and others. *Stroman Furnace & Engineering*

1771. Furnaces
6-page bulletin on recirculating furnaces. Solution heat treating of aluminum alloys, conveyorized ovens, batch-type and car-bottom furnaces. *Despatch Oven*

1772. Furnaces
Lists of surplus furnaces for sale. *Joe Martin Co.*

1773. Fused Silica
Folder on fused silica which is resistant to high temperatures, thermal shock, acids and has high electrical insulating value. *Amersil*

1774. Gas Analysis
Bulletin No. 306 on gas analysis kits for on-the-job determinations of carbon dioxide or oxygen in flue gases, furnace



DEMONSTRATION UNIT for the Casement Window Operator, a product of The H. S. Getty & Company, Inc., subsidiary of Trans Continental Industries, Inc. At left on sill is Anaconda Die Pressed Forging for the operating arm gear. To its right is the finished part after trimming operations around circumference of gear head and in the hole—and hobbing teeth in. Upper right: hinge blank cut from long mill length of an Anaconda Extruded Shape – blank with slots milled and pinholes drilled in knuckles – finished hinge leaf.

How Anaconda die pressed forgings and extrusions cut costs for Getty*

Forgings save 30%. The H. S. Getty & Company, Inc., Philadelphia, is a leading manufacturer of marine, window and builders' hardware. They used to fabricate the operating arm gear for their casement window operator (above) from a leaded sheet brass stamping. The American Brass Company suggested a switch to die pressed forgings. Getty tried it, doing a trimming operation in the hole and periphery of the head – then hobbing in the teeth. Metal saving on each unit was 7 ounces. Machining was cut 10% – for an over-all saving of 30%.

Extruded shapes cut machining and finishing. The illustrations above right show the steps in fabricating Getty butt hinges from an Anaconda extruded shape. This short cut to a superior product gave Getty a simplified shop production routine that eliminated several costly machining and finishing operations – because the extruded shape has the exact cross section of the finished hinge. And, because of the dimensional accuracy of extruded shapes, each part is readily adaptable to drill jigs and milling fixtures. These precision hinges will perform well, too, because extruded metal is *wrought* metal – tough, strong, and dense-grained.

Find out how Anaconda short cuts can help you. If the production possibilities of die pressed forgings or extruded shapes look promising to you, send us a sketch, sample, or description of each part you have in mind. We'll be glad to tell you about costs – and about possible savings, too. Address: The American Brass Company, Waterbury 20, Connecticut. 5778

*Subsidiary of Trans Continental Industries, Inc.

ANACONDA®

DIE PRESSED FORGINGS
EXTRUDED SHAPES

MADE BY THE AMERICAN BRASS COMPANY

atmospheres and other gas mixtures. *Burrell*

1775. Gas Blenders
Bulletin GB 8-57 on machine to control gas mixing. *Gow-Mac Instrument Co.*

1776. Globar Furnaces
Bulletin 153 describes nine types of furnace using silicon carbide heating elements for temperatures to 2600° F. *Hevi Duty*

1777. Gold Plating
8-page paper gives bath composition, equipment and operating conditions, and metallurgical characteristics of 24K gold plate on various base metals. *Sel-Rex*

1778. Gold Plating
Article on analysis of gold and gold alloy plating solutions gives all currently available procedures. *Technic*

1779. Graphite
20-page brochure on significance of graphite as electrodes, anodes, molds, and specialties in electrometallurgy and electrochemistry. *Great Lakes Carbon*

1780. Graphite
4-page folder on graphite crucibles, funnels, and special preformed electrodes. High-purity powder. *United Carbon Products Co.*

1781. Grinding
24-page booklet on tool room grinding of alloy, high-speed and dies steels. Abrasives, properties and uses, wheel shapes and other topics discussed. *Bonded Abrasives Div., Carborundum Co.*

1782. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

1783. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

1784. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

1785. Hardness Tester
4-page bulletin on portable metal hardness tester for any shape or metal. Ranges, features. *Newage Industries*

1786. Hardness Tester
Catalog 72-1 on Leitz miniload tester for Vickers and Knoop hardness tests. *Opto-Metric Tools, Inc.*

1787. Hardness Testing
Bulletin No. A-18 on Alpha Co. Brinell hardness testing machines. *Gries Industries*

1788. Hardness Testing
20-page bulletin on Vickers machine. Description, accessories, advantages. *Riehle Testing Machines*

1789. Heat Exchanger
Bulletin 132 on sectional heat exchanger for use with quench bath, annealing furnace, wire drawing equipment and other industrial cooling functions. *Niagara Blower*

1790. Heat-Resistant Castings
16-page bulletin on design, foundry practice and applications. *Electro-Alloys*

1791. Heat Treating
Monthly bulletin on used heat treating and plating equipment, available for immediate delivery. *Metal Treating Equipment Exchange*

1792. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

1793. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances. *Holcroft*

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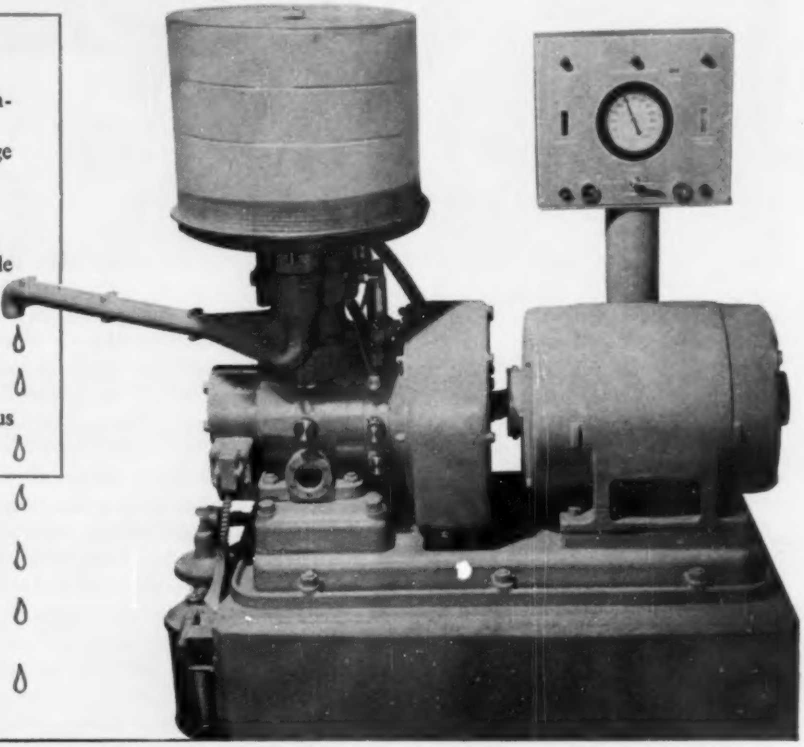

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1794. Heaters
Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

1795. High-Alloy Castings
16-page bulletin No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

1796. High-Strength Steel
Data on low alloy steel. Chemical analysis, physical properties. *Youngstown Sheet & Tube*

1797. High-Strength Steel
Data sheet and 16-page folder on Vasco-Jet 1000, 5% chromium air hardening steel. Mechanical properties, fatigue strength, heat treatment and surface properties. *Vanadium-Alloys Steel Co.*

1798. High-Temperature Lubrication
Bulletin 423 on colloidal graphite and molybdenum disulfide dispersions and their use for high-temperature lubrication. Case histories. *Acheson Colloids*

1799. High-Vacuum Pump
4-page bulletin on small, air-cooled, compound, high-vacuum pumps. *Kinney Mfg.*

1800. Humidity Chamber
2-page brochure on humidity chamber with programming recorder. *Blue M Electric Co.*

1801. Humidity Instruments
New 22-page bulletin on indicating, recording and controlling wet and dry bulb instruments and psychrometers. *Bristol Co.*

1802. Induction Heating
12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

1803. Induction Heating
8-page catalog section 22C on induction heating for forming and forging. Advantages of induction heat. *Ohio Crankshaft*

1804. Induction Heating
36-page bulletin on high-frequency induction heating unit for brazing, hardening, soldering, annealing, melting and bombarding. *Lepel*

1805. Induction Heating
Folder on high-frequency induction heating includes diagram of water-cooled, air-cooled and variable output work unit. *Cincinnati Milling Machine Co.*

1806. Induction Heating
Folder 15C8053C gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers*

1807. Induction Melting
Bulletin 70 on furnace. Controls, designs. *Inductotherm Corp.*

1808. Industrial Equipment
12-page catalog on finishing systems, cleaning, pickling, rustproofing equipment, ovens, conveying equipment. *R. C. Mahon Co.*

1809. Insulators
Bulletin P1-55 on insulators and insulating tubing. *McDanel Refractory Porcelain*

1810. Investment Casting
Two-color chart showing composition and properties of alloys used for investment castings. *Alloy Precision Castings*

1811. Lab Test Dies
Complete information on multi-motion laboratory test specimen dies. *Haller*

1812. Laboratory Furnace
Box furnace with cooling chamber for use to 3100° F. described in bulletin GEA-4713. *General Electric*

1813. Laboratory Furnaces
Bulletin 1016 on single and dual tube furnaces for combustion analysis. *Sentry*

1814. Laboratory Ware
20-page booklet on polyethylene laboratory ware including beakers, bottles, tubing, matting. *Harshaw Scientific*

1815. Leaded Alloy Steel
8-page bulletin gives mechanical properties of Rycut 40, medium carbon fast machining leaded alloy steel. Case studies. *Ryerson*

1816. Leaded Steels
New 16-page booklet on basic characteristics, mechanical properties and workability of leaded steels. Case histories. *Copperweld Steel Co.*

1817. Low-Temperature Alloys
New bulletin on some properties of nickel alloys at low temperatures. Wrought and cast alloys. *International Nickel Co.*

1818. Lubricant
8-page folder describes use of molybdenum disulfide lubricant in cold forming, cold heading and other applications. Case histories. *Alpha Molykote Corp.*

1819. Lubricant
Bulletin on lubricant used in drawing earth satellite shell. *Acheson Colloids*

1820. Lubricant
8-page booklet, "Biggest Ounce of Protection," tells of lubrication with colloidal graphite products. *Grafo Colloids*

1821. Magnesium Extrusions
Article in Magnesium Topics, V.8, No. 2, describes large extrusion press and its companion equipment. *Dow Chemical*

1822. Magnesium Extrusions
36-page bulletin gives values of moment of inertia, section modulus and radius of gyration of bars, tubing, angles, channels, tees, zees and other sections. *Dow Chemical*

1823. Marking Metal
Bulletin on electromark process. Equipment. Operating instructions. *Electromark Corp.*

1824. Melting Furnaces
28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

1825. Melting Guide
Selector guide for heating equipment and control for solder, tin and lead melting. *General Electric Co.*

1826. Metal Crystals
Bulletin on large single metal crystals and polycrystals. *Flow Corp.*

1827. Metallograph
8-page catalog E-240 on research metallographic equipment discusses microscope unit, illuminator, optical equipment, camera, focusing arrangements. *Bausch & Lomb*

1828. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

1829. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

1830. Mixers
20-page booklet B-103 on fixed mounting propeller-type fluid mixers. Mixing capacities, standard sizes and speeds. *Mixing Equipment*

1831. Moisture Measurement
12-page bulletin on how to measure water vapor in air and other gases. Gravometric, dew point and wet and dry bulb methods, and others. *Pittsburgh Lectrodryer*

1832. Molybdenum
8-page reprint on arc-cast molybdenum describes machining procedures, tools and equipment. How to machine a turbine wheel. *Climax Molybdenum Co.*

1833. Nickel Alloy
12-page booklet on Hastelloy Alloy R-235, vacuum-melted wrought alloy containing aluminum and titanium. *Haynes Stellite Co.*

1834. Nitriding
Data on process for nitriding stainless steel. *Standard Steel Treating*

1835. Nitrogen Generator
6-page bulletin No. I-100 gives flow diagram and explains operation. *C. M. Kemp Mfg Co.*

1836. Nondestructive Inspection
8-page bulletin on use of ultrasonic Reflectoscope describes principles of ultrasonic inspection and its uses. *Sperry Products*

1837. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

1838. Nondestructive Testing
4-page bulletin on ultrasonic equipment. Accessories, immersion tanks, transducers. *Curtiss-Wright Corp.*

1839. Nonferrous Wire
Folder gives wire gage and footage chart and data on beryllium copper, phosphor bronze, nickel, silver, brass and aluminum wire. *Little Falls Alloys*

1840. Ores
8-page description of the Colorado plateau, its industries, ores, mining and metallurgy, Vancoram Review, Spring-Summer, 1957. *Vanadium Corp.*

1841. Ovens
16-page bulletin No. 53 on various types of core and mold ovens, special ovens and heat treating furnaces. *Carl Mayer*

1842. Oxygen Recording
Data sheet 643(5) on magnetic equipment for recording oxygen content of exhaust gases. Sampling system and measuring system. *Leeds & Northrup*

1843. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

1844. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

1845. Plated Strip
Bulletin on plated metal strip. Plating thicknesses and variations possible. *Sylvania Electric*

1846. Plating
Data and specification sheet covering tin plating a wide range of nonferrous thin strip metals. *Somers Brass Co.*

1847. Plating
New 8-page bulletin on automatic plating and anodizing machine. Deposition charts for nickel tin, zinc, cadmium, copper. *Lasalco, Inc.*

1848. Plating Solutions
Operating manuals for plating with metal fluoborate solutions. *Baker & Adamson.* See page 177.

1849. Precision Casting
4-page bulletin on Accu-Cast method of casting mold and die components without subsequent machining. *Manco Products*

1850. Precision Casting
12-page book on alloy selection and design for investment casting. *Arwood Precision Casting*

1851. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

1852. Precision Castings
20-page book on alloys used, specification ranges, advantages and castings made by precision casting. *Haynes Stellite*

1853. Precious Metals
Data on bright gold, bright silver, rhodium plating and salts. *Sel-Rex*

1854. Product File
30 new products and 500 pieces of literature described in 20-page reprint of items appearing in monthly magazine during third quarter, 1957. *Metal Progress*

1855. Protective Coatings
Folder 301 on industrial protective coatings of rubber, neoprene and other materials. *Arco Steel Fabricators*

1856. Pure Metals
20-page brochure on pure metals, master alloys and ferro alloys. Chemical analysis, powder mesh sizes, vacuum melting grades. *Shieldalloy*

1857. Pyrometer
Catalog 95 gives advantages, applications, operating procedure, accessories. *Pyrometer Instrument Co.*

1858. Pyrometer
12-page bulletin on contact pyrometer for surface temperatures describes and illustrates instrument and its uses. *Illinois Testing Laboratories*

1859. Pyrometer Supplies
56-page bulletin P1238 on thermocouples and pyrometer accessories. Engineering data on selection and installation. *Bristol*

1860. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

1861. Quenching Oil
Bulletin 37 on light quenching oil. Effect of agitation on quenching speed. *Sun Oil*

1862. Radiography
28-page booklet on products for industrial radiography gives exposure and processing data for various films used. *Du-Pont, X-Ray Div.*

1863. Radioisotopes
8-page booklet on cobalt-60, cesium-137, iridium-192 and how they are used in radiography. Gamma and X-ray radiography compared. *Ansco*

1864. Recorders
4-page data sheet E-ND46(6) on millivolt recorders. Specifications. *Leeds & Northrup*

1865. Refractories
24-page bulletin on mullite refractory brick. Shapes, conductivity of refractory materials. *Refractories Div., H. K. Porter*

1866. Refractories
New 24-page manual on mortar preparation and general instructions. Bibliography. *Lumnite Div.*

1867. Refractories
8-page catalog of super refractory shapes, tubes, insulators for use to 3542° F. *Morganite, Inc.*,

1868. Refractory
Bulletin on castable refractories. How to
(*Continued on page 48-A*)

This spindle turns at 10,000 RPM without a jitter—that's the benefit of Welded Carbon Steel Tubing's "on-center" uniformity of roundness, wall thickness and concentricity.

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The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

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(Continued from page 46)
use them. Properties of four types. *Standard Fuel Engineering*

1869. Refractory Coating
Data on aluminum oxide and silicon carbide coating which may be sprayed on. *Norton Co.*

1870. Resistance Alloys
New 20-page booklet M-57A on 80-20 nickel-chromium alloy. Heating element design data. Metallurgical factors which affect high-temperature operations. *Hoskins Mfg.*

1871. Resistance Welding
24-page catalog on equipment for resistance welding includes reference tables and property and application charts. *Ampco*

1872. Rust Prevention
New 16-page booklet on corrosion testing, standard rust preventives. Selection chart. *E. F. Houghton*

1873. Rust Prevention
Data sheets describe solvent type and emulsifiable type rust resisting compounds. *John Swift Chemical*

1874. Rust Preventive
Bulletin 22 on water-soluble rust preventive for cast iron and steel. *Production Specialties*

1875. Salt Baths
Bulletin H-1 and G-1 on neutral salt baths and their operation and heat treating high speed steel in salt baths. *Park Chemical*

1876. Sand Control
32-page book on defects and troubles in foundry and how to remedy them through sand control. *Claud S. Gordon*

1877. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

1878. Seamless Tubing
8-page bulletin TB340A, guide to the choice of seamless mechanical tubing, tells how it is manufactured and finished, dimensional tolerances, costs, machinability. *Babcock & Wilcox*

1879. Shaker Hearth Furnace
Bulletin HD-850A on furnace for carburizing, cyaniding, hardening. Quench system, temperature control. *Hevi-Duty Electric Co.*

1880. Shell Castings
34-page brochure on shell castings from design through cost analysis. Parts cast. *Central Foundry Div.*

1881. Shell Mold Castings
Data sheet on castings of beryllium copper alloys by the shell molding process. *Ampco Metal*

1882. Shell Molding
4-page reprint on how use of shell cores eliminates machining of large stainless steel castings. *Cooper Alloy Corp.*

1883. Shot and Grit
14-page catalog describes cast steel, malleable iron, chilled iron, cut wire and other forms of abrasive shot and grit. Methods of shot peening and impact cleaning. *Abrasive Shot & Grit Co.*

1884. Shotblasting
16-page "Primer on the Use of Shot and Grit". Problems of blast cleaning operations. *Hickman, Williams*

1885. Silicon Carbide
8-page booklet on silicon carbide refractory. High-temperature properties. Shapes. Design practices. *Refractories Div., Carborundum Co.*

1886. Sintering
8-page folder on batch and continuous-type sintering furnaces and atmospheres for sintering. *Lindberg Engineering Co.*

1887. Slitting
76-page handbook on multiple rotary slitting lines. Design, selection and operation of slitters. Specifications and capacity tables. *Yoder Co.*

1888. Sodium
28-page booklet on using sodium in dispersed form tells how dispersions are prepared and handled, and their advantages. *Ethyl Corp.*

1889. Solvent Cleaning
16-page booklet on how to use solvent detergents for removing carbon, grease, dirt, paint. *Oakite Products*

1890. Spectrograph
New 8-page catalog on Spec-Lab. Performance and applications of three models. *Jarrell-Ash*

1891. Stainless Steel
New 28-page booklet on properties and applications of 17-4PH and 17-7PH stainless. Fabricating procedures. *Armco Steel*

1892. Stainless Steel
New 44-page manual on stainless steel products for architects and builders. Where to buy factory-made components. *American Iron and Steel Institute*

1893. Stainless Steel
Data sheet on Type 301 gives physical properties, corrosion and oxidation resistance, mechanical properties. *Allegheny Ludlum*

1894. Stainless Steel
Selector gives machinability, physical and mechanical properties, corrosion resistance of various grades of stainless steel. *Crucible Steel*

1895. Stainless Steel
36-page bulletin of effect on properties of processing at different temperatures. *International Nickel*

1896. Stainless Steel
12-page bulletin on chromium-manganese austenitic steel. Effect of cold working, properties at elevated temperatures, corrosion resistance, magnetic permeability. *U.S. Steel Corp.*

1897. Stainless Steel
28-page book on type 430 nickel-free chromium stainless. Properties, surface characteristics, fabrication, applications. *Washington Steel Corp.*

1898. Stampings
6-page folder tells how deep drawn stampings are produced. *Transue & Williams*

1899. Steel
14-page manual on sizes and types of electric furnace steel. List of products equipped to roll. *A. M. Byers*

1900. Steel 52100
Stock list on 52100 tubing, bars and ring forgings. *Peterson Steels*

1901. Steel Bars
Wall Chart of AISI grades of cold finished steel bars. Carbon, alloy and leaded grades. *LaSalle Steel*

1902. Steel Castings
32-page bulletin tells how castings are made, how they are designed and specifications for steel castings—heat treatment, chemistry, properties. *Keokuk Steel Casting Co.*

1903. Steel Castings
Two bulletins on medium and medium high carbon steel casting specifications. Allied specifications, analysis, properties, hardenability. *Unitcast*

1904. Steel Tubing
12-page booklet on uses of seamless and electric resistance welded steel tubing in materials handling equipment. *Ohio Seamless Tube Div.*

1905. Stress-Strain Recorders
28-page bulletin No. 4215 on 16 standard recorders and 50 models of strain fol-

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lowers, for use on standard testing machines. *Baldwin-Lima-Hamilton*

1906. Temperature Conversion
16-page temperature conversion booklet and electromotive force of thermocouple alloys in absolute millivolts. *Wheelco*

1907. Temperature Measurement
New 24-page catalog of heat radiation detectors for continuous temperature measurement to 5000° F. *Leeds & Northrup*

1908. Temperature Measuring
New folder on metal probe thermometers. Types, specifications, accessories. *Royco Instruments*

1909. Tempilstiks
Folder 571 on Tempilstik, pellets and Tempilaq, temperature indicating devices. *Tempil° Corp.*

1910. Testing Machines
Bulletin on Brinell hardness, ductility, compression, tensile, universal, transverse, hydrostatic proving instruments. *Steel City Testing Machines*

1911. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

1912. Thermocouples
Chart of color codes and calibration for thermocouples and extensions. Resistance tables for pyrometer wires. *Thermo Electric*

1913. Thickness Gage
Folder on pocket-size gage. How to use it. *Ferro Corp.*

1914. Thickness Tester
Data sheets give ranges, principle of operation of nondestructive thickness tester. *Unit Process Assemblies*

1915. Titanium
8-page booklet on corrosion resistance of titanium. Table of ratings of titanium compared with stainless and aluminum in various mediums. *Mallory Sharon*

1916. Tool Steel
Color guide to estimate temperatures has heat colors on one side and temper colors on the other. *Bethlehem Steel*

1917. Tool Steel
44-page stock list is indexed and includes sizes, weights, and analyses. Decimal conversion and hardness conversion tables. *Uddeholm*

1918. Tool Steels
New 12-page booklet on tooling for hot extrusion. Selecting and heat treating of tool steels. Design, cooling, setup and finish. *Crucible Steel*

1919. Tools and Dies
New 8-page brochure on eliminating cracking hazards in the manufacture of tools and dies. Design, how to make the tool, heat treatment and selecting the steel. *Carpenter Steel Co.*

1920. Tube and Bar
Bulletin 156 on Meehanite and Ni-Resist tube and bar stock. Properties and uses. *Centrifugally Cast Products Div., Shenango Furnace Co.*

1921. Tubing
8-page folder (TB-419) on electric resistance welded mechanical tubing. Properties, tolerances. *Babcock & Wilcox Co.*

1922. Tubing
12-page booklet on tubing for the refrigeration industry. Spun end and finned tubular products. *Wolverine Tube Div.*

1923. Tukon Tester
12-page bulletin-328 on Tukon micro and macro hardness testers. *Wilson Mech. Inst.*

1924. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

1925. Ultrasonic Cleaning
12-page article on new ultrasonic cleaner for use with metallographic specimens. Metal Digest, V.3, No.1. *Buehler, Ltd.*

1926. Ultrasonic Cleaning
4-page bulletin on ultrasonic washing and degreasing equipment. Capacities, specifications. *Curtiss-Wright Corp.*

1927. Ultrasonic Machining
16-page bulletin lists typical machining operations, materials which may be machined ultrasonically, machine features and accessories. *Sheffield Corp.*

1928. Vacuum Furnace
6-page data sheets on high-vacuum furnace for operation at 3600° F. Specifications and operating characteristics. *Richard D. Brew & Co.*

1929. Vacuum Furnaces
8-page bulletin 552 on high vacuum furnaces. Equipment and methods for vacuum melting. Vacuum treating—annealing, heat treating, degassing, brazing, sintering. *High Vacuum Equipment Corp.*

1930. Vacuum Furnaces
Articles on commercial vacuum furnaces for metals and alloys and some aspects of vacuum melted metals. *National Research*

1931. Vacuum Furnaces
Bulletins P8-20 and P4-28 on vacuum arc melting furnaces and pumps. *Consolidated Electrodynamics, Rochester Div.*

1932. Vacuum Metals
File of data on vacuum-melted metals and their applications for bearings and in the chemical industry. Development of the vacuum metals. *Vacuum Metals Corp.*

1933. Vacuum Pumps
16-page booklet on maintenance of vacuum pumps. *Stokes*

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6-page bulletin on spot and projection press welders. Specifications and optional features. *Precision Welder & Flexopress*

1935. Welding
Data on welding positioners from 500 to 100,000 lb. capacity. *Harnischfeger*

1936. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

1937. Welding Stainless
New 12-page booklet—a guide to better welding of stainless steels. In question and answer form. *Arcos Corp.*

1938. Wire Cloth
New 94-page catalog on line of industrial wire cloth, screen and wire cloth products. Types, sizes, applications. Metals and alloys used, stainless compositions, corrosion tables. *Cambridge Wire Cloth.*

1939. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

1940. X-Ray Diffraction
4-page bulletin on X-ray diffraction cameras. 7 models described. *Jarrell-Ash*

1941. X-Ray Equipment
Bulletin RC-212 on equipment for element analysis and structure determinations. Diffraction apparatus and cameras. Spectrograph. *Philips Electronics*

1942. X-Ray Inspection
Folder on 300 kvp. inspection unit. Cutaway diagram. Basic designs. *General Electric, X-Ray Div.*

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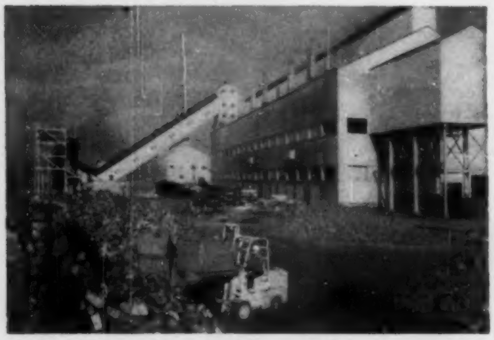

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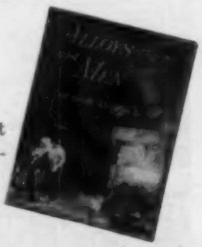

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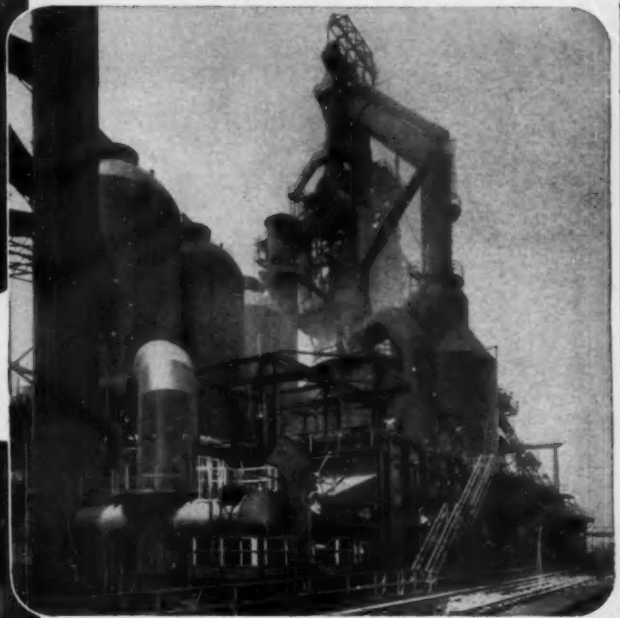
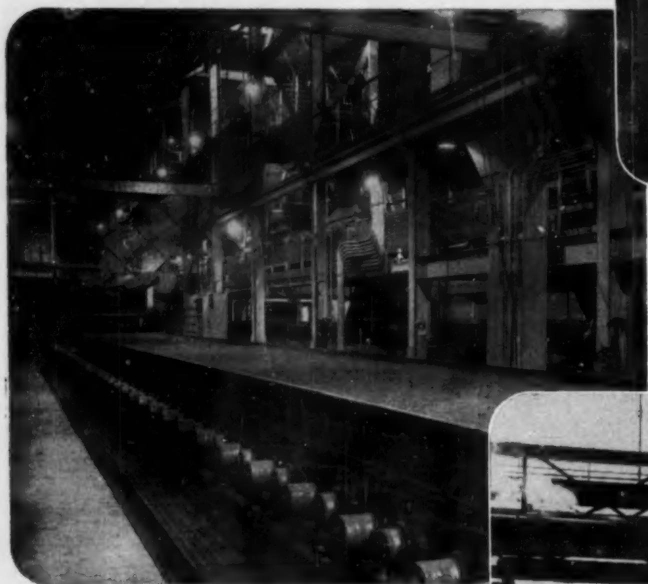
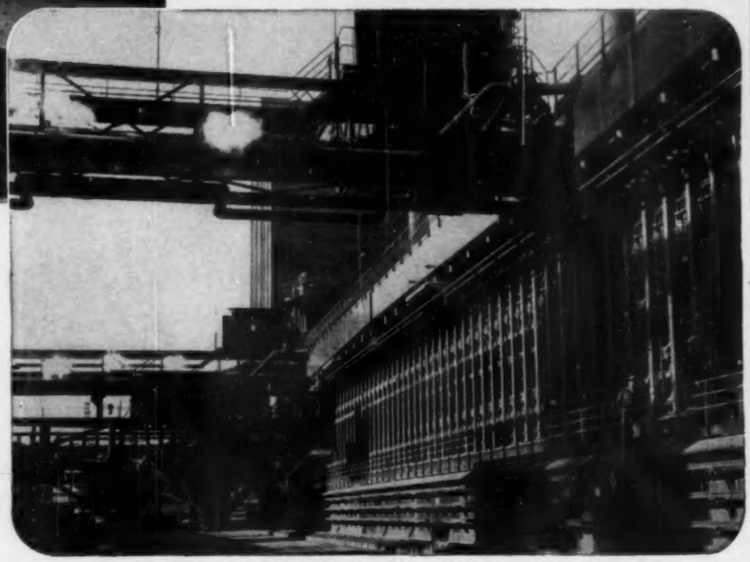


Biggest in the world, "A" blast furnace was designed and erected for Great Lakes Steel Corporation by the Freyn Department of Koppers. It has a hearth diameter of 30 feet, 3 inches . . . a total interior volume of 64,435 cubic feet.



8-foot-wide sintering machine, designed and constructed for Weirton Division of National Steel in 1955. This machine produces over 2,500 net tons of blast-furnace sinter a day. Now, Koppers Freyn Department is building two complete sintering plants—each with a 12-foot-wide machine—for National Steel Corporation.



87 Koppers-Becker Coke Ovens, installed by Koppers Coke Plant Department in 1956 for Inland Steel Company's Indiana Harbor Works. This battery carbonizes 1,920 net tons of coal per day and is similar in design to an earlier battery of 65 Koppers Coke Ovens built in 1950.

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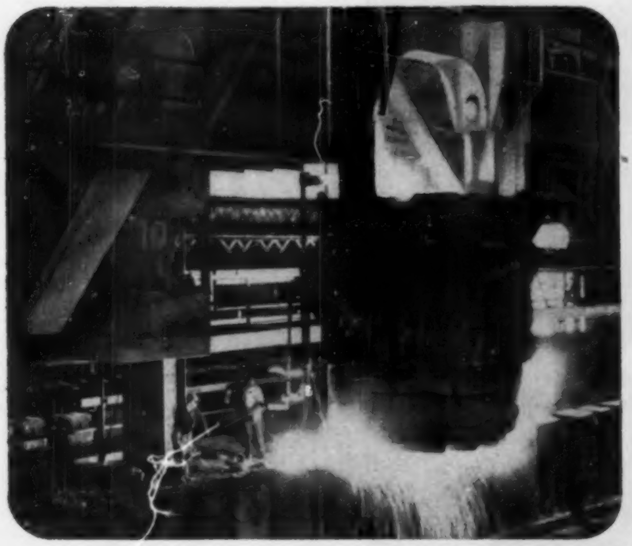
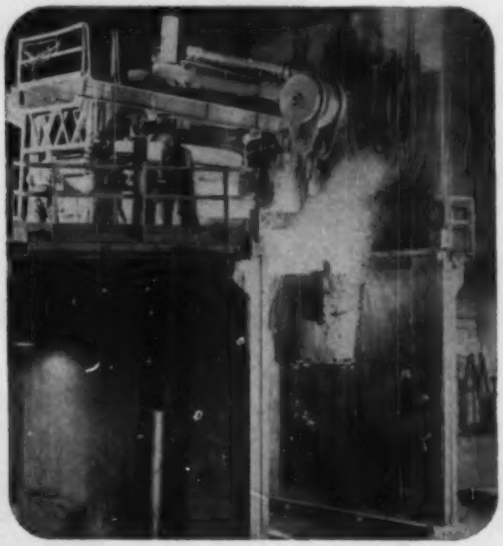


This open-hearth shop, with eight furnaces, was designed and engineered for Youngstown Sheet & Tube Company by the Freyn Department of Koppers. Rated annual ingot capacity of the furnaces is 1,776,000 net tons. Koppers also designed a complete slabbing mill for this same company.



Electric-furnace shop, engineered and built in 1952 by Koppers Freyn Department to produce stainless and specialty steels for Allegheny Ludlum Steel Corporation at Watervliet, New York.

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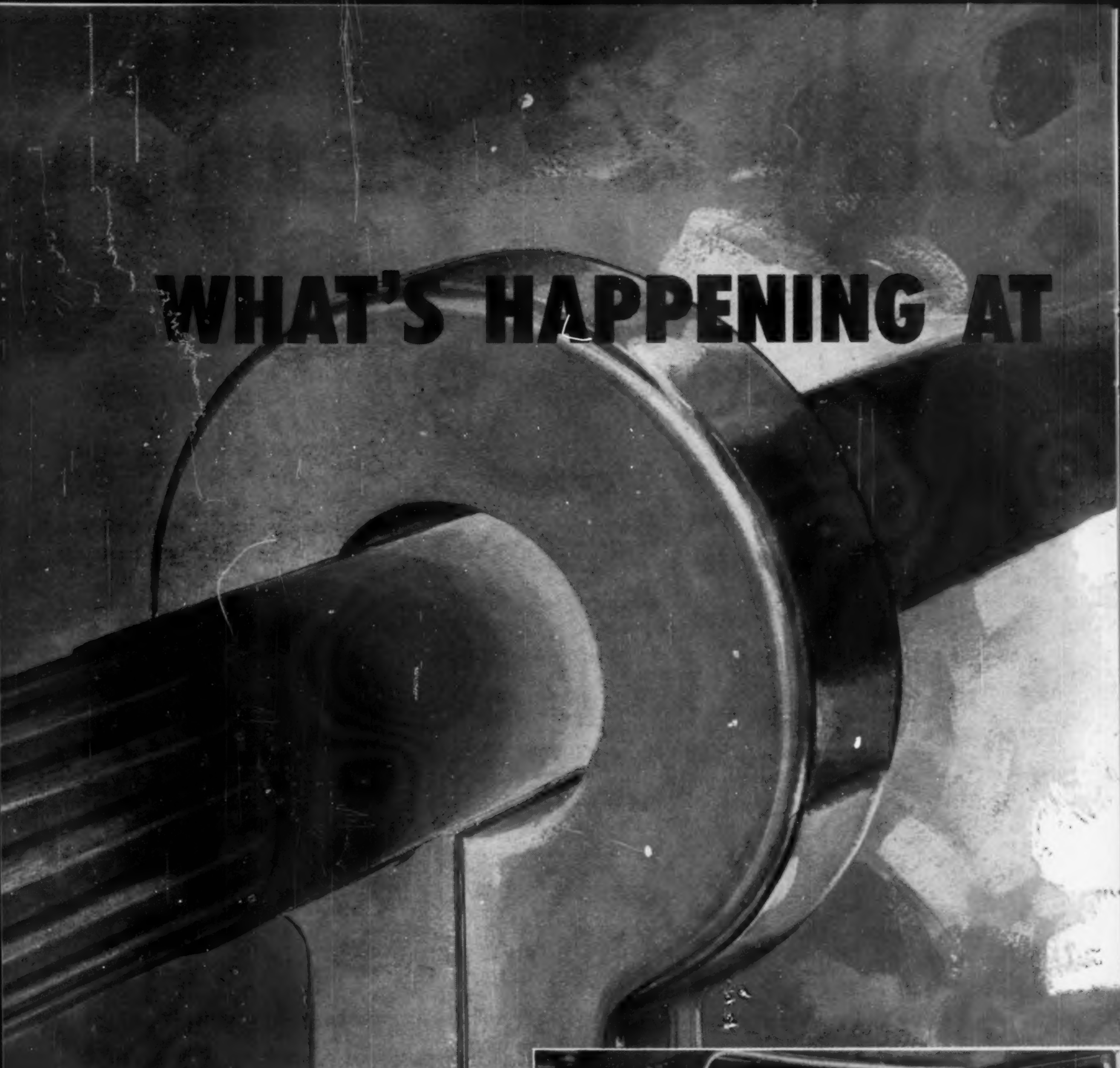

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Closeup of wheel-and-brake test fixture showing hydraulic pump used to apply brake pressure.

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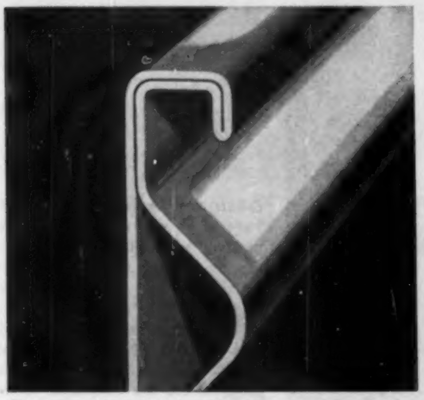

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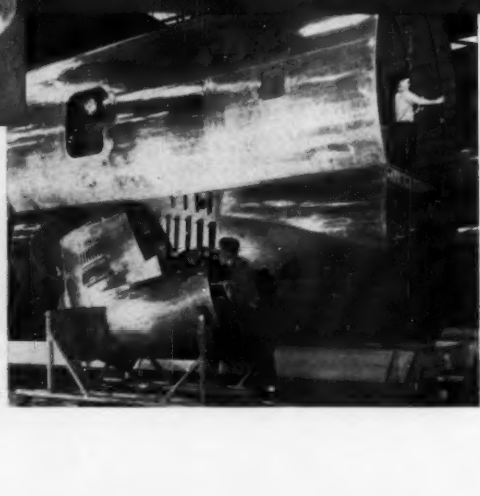

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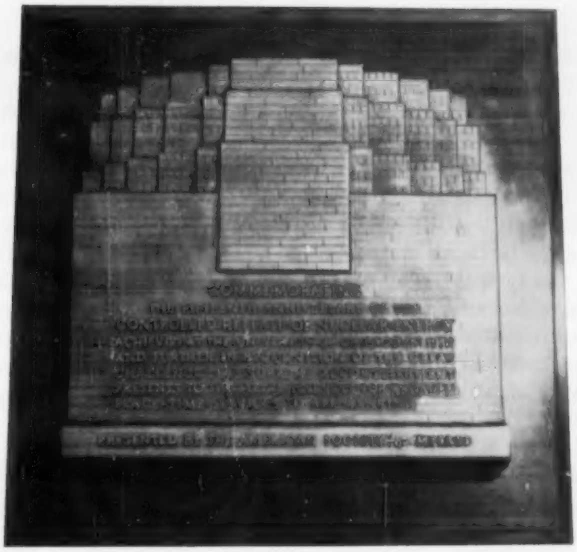


The Nuclear Chain Reaction

During the National Metal Congress 18 of the 42-man crew who were present when the first atomic pile "went critical" attended the 15th anniversary and the presentation of a commemorative bronze plaque to the University of Chicago by the American Society for Metals. These four addresses – largely reminiscent – were presented by men prominent in that truly historic project. (W11p, T11, 17-7, A2)

The Fundamental Experiment

*By SAMUEL K. ALLISON**

IN THE BEGINNING there were three chain reaction projects in the United States – at least three known to me. There was one at Columbia under Fermi and his group. There was work going on at Princeton with Prof. Wigner and Ed Creutz. Somewhat as late arrivals there was a group under my direction working here in Chicago. Largely at the pushing of Gregory Breit, who always was wanting me to do twice as much as I was able to do and spend twice as much as I thought ought to be spent, we did collect a gram of radium and a lot of graphite and some uranium oxide. Gregory wanted me to go right ahead and do practically the same thing that was being done at Columbia. I thought this was *lese majesty*, but I did it.

I remember we had collected enough materials to stack up into an exponential pile and see if the reaction would go—meaning that if we had enough more of the same material we could make a full-scale device. At one of the endless "organization" meetings we were having in New York, I gave up and went down to Princeton where Wigner and Creutz gave me a day's working over and persuaded me that the uranium oxide lumps I had prepared for the first structure were too big.

I said, "Well, what am I going to do about it?"

They said, "Saw them in two."

I said, "Well, I had a terrible time getting

*The Enrico Fermi Institute for Nuclear Studies, University of Chicago.

them pressed so that they would hold together. They were falling apart most of the time. Here you want me, after all this, to saw them in two."

They said, "Well, you'd better saw them in two."

I said, "I've got one along with me in my bag. If you will saw it in two and prove to me it can be done, I will see what I can do about it."

In typical fashion, Ed Creutz grabbed a hacksaw and sawed it in two, much to my horror. It stayed together in the two parts, so I was convinced, and I came back to Chicago and we proceeded to saw up all the pressings we had made. A lot of them fell apart, as I predicted, but we did get away with it, and we stacked up an exponential pile. We took the gram of radium and took the measurements. I had to be coached all the time by Fermi, but we at least could carry out instructions, and we got the result that "*k*", the famous "*k*" that had to be greater than one in order to build the machine, was 0.93.

The Columbia pile, the first exponential pile, had been stacked up several months previously and only gave 0.87 for k. Fermi didn't believe and shouldn't have believed my result, so he came here and insisted on seeing all the original data. He sat down and figured out the multiplication factor and he got 0.95, and I could see this annoyed him. He hated to have anybody more conservative than he was! Since then, every time he would mention 95 as the Chicago first experiment, I would quietly say "Ninety three" just to annoy him, and it obviously did annoy him. There was a possibility of interpreting the data we had at that time in these two different ways.

Of course, I would like to pretend that $k = 0.95$ was due to my superior scientific ability and sagacity. However, as usual, there is a more mundane explanation, namely that the uranium oxide we received from Canada was simply better than the uranium oxide in the first shipment that had gone to Columbia. It was much purer and had less competitive absorption, so it did work better.

Shortly after that, the Columbia team moved out here with Herb Anderson and the rest of them, and they were obviously so capable with these piles that I rapidly went out of business. However, I had been impressed that the problem was essentially one of purity of the materials, and I remember that I decided (this was during the late spring of 1941) to devote my efforts toward getting lots of pure materials with no competitive absorption. Actually, I found myself editing and circulating a secret bi-weekly journal of analytical chemistry!

So the long quest for purer and purer materials went on. It was very difficult to persuade the people that made graphite that their graphite wasn't pure enough. Nobody had ever complained about impurities in their graphite before, and certainly nobody had ever complained about boron in their graphite. They were unaware there was any in it at all, and they couldn't conceive of any possible harm it might do. The business of educating and encouraging the people to make boron-free graphite was a big one – especially when you couldn't explain *why* you needed it.

Then there was the business of making pure uranium compounds. While very little attention had been paid to uranium chemistry at that time, we knew that to make pure uranium compounds you simply extracted uranyl nitrate with ether and recovered the fraction that went into the ether. The only trouble was that most chemical concerns were deathly afraid of using ether on a large scale. We finally found the Mallinckrodt Chemical Works in St. Louis, and after they went into production there was no trouble about pure uranium salts.

The next trouble was to get pure metal from pure salt. I can well remember when the only sample of uranium in the United States was a 5-g. piece on Lyman Briggs' desk in the Bureau of Standards. We needed tons of the stuff and it had to be pure. My first contact with a feasible process for making pure uranium metal was through the British. Mr. Ferguson came over from Imperial Chemical Industries and told us – or told me – that they had succeeded in reducing tetrafluoride with magnesium or calcium.

This idea was quickly put into operation at the Ames Laboratory in Iowa, and pretty soon uranium began to come in. In May 1942 there was enough good material, good uranium and good graphite, so that an exponential pile was set up by the Columbia group and Fermi announced that k was greater than one, and that if enough of this material could be provided the chain reaction would certainly go.

I remember this event with some pain because of my usual skepticism. I had just gotten home from one of the innumerable meetings we had with various high officials in Washington. Arthur Compton, with his usual optimism, had announced that there was no doubt that the chain reaction would go with natural uranium and graphite. He produced a set of figures on the

blackboard and added up the little fractions and came out with $k = 1.08$ or something like that. I embarrassed him by saying I didn't believe the figures. I thought he had been a little bit too optimistic about graphite as a moderator and I was afraid that they were throwing overboard the heavy water possibility too soon.

This must have been in late April 1942, but in two or three weeks there was no doubt that the thing would succeed. I remember I wrote a letter saying *mea culpa* to Mr. Conant and

Chancellor Kimpton

said that the last skeptic was now convinced and that there was no doubt that the chain reaction with natural uranium in graphite would go.

You may well question what happened in the period between May 1942 and December 1942. It was mostly just getting in shipments of pure material. This was a question of making tons, not grams, of boron-free graphite and boron-free uranium metal and uranium oxide. The metal problem was more than getting it boron-free – it was to make the metal at all! Until Ames started to reduce the halogen compounds, the uranium powder we got from oxide reduced by lithium hydride was much more dangerous than any chain reaction we might have started! In opening the cans, we several times found stuff too poorly sintered; it was essentially a pyrophoric powder. The uranium that we were supposed to put in the pile would catch fire, people would throw water on it, and that only made it worse.

All these difficulties gradually were overcome. By the late fall of 1942 it became clear that in a few weeks we would have the chain reaction.

The Eventful Day

*By HERBERT L. ANDERSON**

For me the eventful day began at midnight December 1. I was the straw boss of the building of the pile. My job was to build the pile layer by layer and to see to it that the graphite and uranium were put on in their proper places. The progress of the construction was followed by the counting rate recorded by a boron neutron counter inside the pile. The increase of these counts, together with the size of the pile as the structure grew, was an index of the approach to criticality. These data were methodically plotted on a graph which Fermi kept always on hand.

On this day our measurement showed that the pile would reach criticality at the 56th layer. It seemed certain that we would complete this on the night of December 1. We had become quite skilled at our work after six weeks of construction so that it wasn't long before this point was reached. The neutron count taken with one cadmium rod in place was in fact at the anticipated level. One more layer, the 57th, and the job would be done. I could send the crew home and survey our completed handiwork.

Standing there alone, atop that huge granite and uranium semisphere, there came upon me a great temptation: I could withdraw the remaining cadmium control rod – only for a moment – and I could be the first man on earth to start a chain reaction. The trouble was that earlier in the day Fermi had guessed that I might have this temptation. He had extracted a solemn promise from me that, once the agreed-on level had been reached, I would take the count and if it was as expected, put in all the cadmium rods and go home to bed. This, I'm afraid, was exactly what I did. At 3 a.m. the stage was set. We had a chain reaction ready to go.

What happened the next day was like a rehearsed performance. Fermi – now in the center of the stage – had calculated so exactly the whole behavior of that pile that he could announce beforehand the response of the pile. He could then call for the withdrawal of the cad-

*The Enrico Fermi Institute for Nuclear Studies, University of Chicago.

mium control rod and the meters would show how correct he was.

It was a masterful performance, as many of you here will recall. You remember when Fermi announced that now he would make the pile go critical, that the counting rate would climb and climb until he chose to throw in the controls – how we held our breath when the activity had risen to what seemed an uncomfortable level, and it wasn't until we were all becoming somewhat alarmed at the rapid clicking of the counter that Fermi waited just a bit longer and then gave the order to throw in the controls. How relieved all of us were to hear how promptly the activity fell off. The chain reaction! What a well behaved giant it was!

Four of the Speakers at the Anniversary Ceremony. From left – Murray Joslin, vice-president, Commonwealth Edison Co., whose talk is not reproduced here; Dr. Allison, Dr. Anderson and Dr. Chipman

Wartime Work

*By LAWRENCE KIMPTON**

I have written a very elevating address which I planned to read when accepting this bronze plaque, acting as representative of the truly great men who carried through one of the most extraordinary projects this world has ever known. However, at this moment it seems to me to be quite inappropriate. Instead, let me reminisce here in the congenial presence of so many of the original team.

I served as chief administrative officer of the Metallurgical Laboratory beginning in mid-1943, after the chain reaction Dr. Anderson has so vividly recalled and continuing until the end of the War – an administration which was once described, I believe, by Ed Creutz in this way: "Never have so many done so little for so much."

How singularly accurate that was! May I begin, however, at the time when I was serving as dean and director of a junior college out in the desert country in California. One summer a mutual friend brought Jim Conant down to our ranch, and while he was there, he looked over our work in chemistry and was very critical. I remember at the time I didn't regard it as any of his business!

But it occurred to me that Harvard was bigger than the school I was operating, and since Conant was a very distinguished chemist perhaps I should pay some attention to him. So he suggested when he was leaving that he was going into Southern California and he would like to send Linus Pauling up from California Institute of Technology. Pauling did come up. He fell in love with the desert country too, helped us in our work in chemistry and sent some of his

*Chancellor, University of Chicago.

very competent graduate students up to continue the work.

It was in this way that I met Charley Coryell, in particular, who joined the Metallurgical Laboratory and apparently persuaded someone that if you could run a weird little desert school you could be the chief administrative officer of the Metallurgical Laboratory!

In any case a man named R. L. Doan, as I recall, came to see me and asked me if I would serve as his assistant for the direction of this interesting place. I asked him what they were doing up there and he wouldn't tell me. I asked him what I would be doing and he said he didn't have the slightest idea. The only thing he would

Mrs. Enrico Fermi and Dr. Anderson

say was that it was enormously important, very dangerous, and that I ought to do it. So I did.

I remember the first day I arrived on this campus of the University of Chicago. In the meantime Mr. Doan had altogether disappeared and I didn't find out until a year later that he had gone to Oak Ridge. I reported to a man whom I never heard of before, named Munnecke. He said, "You know, the administration of this project is in a mess."

I said, "You ought to know!"

He proceeded to prove it by taking out an organization chart and showing that most of the boxes on it were empty. He explained that either there were no people doing those things or he hadn't been able to find them up to this point – he didn't know which. In any event, he said, he was terribly glad to see me and I said politely I was glad to see him. Then he explained why he was glad to see me. He was going that very day to Washington for some three weeks, and he had no one to run the laboratory in his absence.

I was at that moment the chief administrative officer of the Metallurgical Laboratory without knowing anything in the world about it or what it was supposed to be doing. I remember that I had barely located the drinking fountain and the men's room when a scientist – and I for the life of me cannot identify him now – came in, carefully closed the door and said, "Are you the man that I ought to be talking to?"

The question seemed a little ambiguous in that form, but I said, "Well, I suppose I am."

He said, "I badly need a supersonic reflectoscope." (I had never heard of a reflectoscope, supersonic or otherwise.)

I said, "What do you want it for?"

"Well," he said, "I have a problem of detecting leaks in hot-dog jackets."

I had heard that there was a relationship between Harold Swift and the University of Chicago, but I had no idea I was engaged in a research program for Swift and Co. or any other meat packer. I remember I had the presence of mind to say, "These supersonic reflectoscopes are hard to come by."

He said, "Indeed they are. There is only one in the world at this point. That is owned by General Motors and they developed it themselves and if we ask them for it they might guess what we were doing. But," he said, "we have got to have one and I will leave this with you as a problem."

At that point he walked out of my life too!

I must say that the description I have just given you of my first connection with the project and my first day on it was symptomatic of the whole, but somehow or another we did get a little kind of administrative order. We did somehow get a draw-bench for Ed Creutz and do all of the administrative jobs that had to be done. My memories of that program are still some of the most treasured memories that I have – of the gentle and powerful Fermi moving easily ideas and men and experiments, of dear old James Franck, of Leo Szilard pacing up and down the third floor corridor of Eckhart Hall, of all the great men who were associated with this great project. And in addition to memories, I think I learned some things that are important.

One was that the only value of administration is in terms of a service to the research and academic enterprise. It has no meaning apart from

that. Secondly, I learned that basic research is of enormous value, incalculable value. I learned too that science and industry can move easily and fruitfully together – this I learned as we worked with the Du Pont Co. on the design and construction of the great plant at Hanford.

Some Important After-Effects

*By JOHN CHIPMAN**

As Dr. Allison has mentioned, it was obvious in the early days that the so-called Metallurgical Laboratory had a materials problem on its hands. This turned out to be more than a mere purity problem, important as that was. It turned out to be a many-sided problem of the properties, the preparation, the handling, the fabricating of materials into useful shapes, and preserving them under pile-operating conditions.

To tackle the metallurgical phases of this broad problem, the Metallurgy Section of the "Metallurgical Laboratory" was set up and I would like to mention the names of some of the people that took leading parts in that metallurgy section. There were Frank Foote, Ed Creutz, John Howe, Al Greninger. These men in particular were leaders in that metallurgical research program.

We had the problem of fuel elements. Now, a fuel element for the first pile was a simple thing. In fact, on Dec. 2, I was busy casting fuel elements (small uranium lumps for the Chicago pile) down in a little basement room in Massachusetts Institute of Technology where we were converting that pyrophoric powder into vacuum-cast lumps.

As pile design became more sophisticated, fuel element design became more complicated. Fuel elements had to be designed and built for the pile at Clinton Laboratories and later for the pile at Hanford. Not only was it necessary to design the type of protection but also to assure that each and every fuel element had perfect bonding between its core and its sheath so the heat flow would be completely uninterrupted. Furthermore the enclosure must be perfect so that corrosion would be held away from the uranium surface. *No* leaks were permissible. At this moment perhaps I should thank Chancellor Kimpton for getting us that supersonic reflectoscope. It proved indispensable in development of fuel elements for the Hanford reactor.

In this effort the early plans at Hanford were 100% successful, but not (let me assure you) without much work and worry. The construction of fuel elements is still the metallurgist's problem. As I said just now, they have become more and more complex as pile design has developed, and this is a problem which apparently will always be with the metallurgist. It has become one of his important fields of activity.

The same applies to nuclear devices, bomb devices. I can remember very well, before the war ended, that Cyril Smith at Los Alamos handed me a piece of plutonium nicely gold-plated. As I held it in my hand it felt uncomfortably warm as though it had been stored in an oven. This is one of my vivid memories of the project and my first and only experience with plutonium metal, which will in generations to come be one of the world's most important sources of energy.

We can look forward, then, to metallurgical research and developmental activities in connection with fuel elements and certainly with respect to many other features of the developing atomic nuclear industry. The disturbing thing about the developments which have come since "The Eventful Day" – the many disturbing things are summarized in my mind in this way: The developments have widened the gap between war and peace.

In prehistoric times we may be assured that war and peace were not very different, because people were scrapping anyhow. As civilization has grown, war and peace have become more and more different. Science, applied science and industry have given us innumerable good things; nuclear energy will multiply them. It will also lead to utter destruction if this knowledge is wrongly used. Thus we have come to a *total* difference between war and peace. And it is this totality of difference which has come about from nuclear developments. It is this totality of difference which emphasizes that peace can be a thing so much better than the old world knew.

If we use nuclear energy wisely we can have so much more than our old world was accustomed to. War we can easily visualize. How utterly destructive it would be. This is the terrifying thing that we have brought upon ourselves. I am afraid – I am terribly afraid when someone leads me to the brink of war.

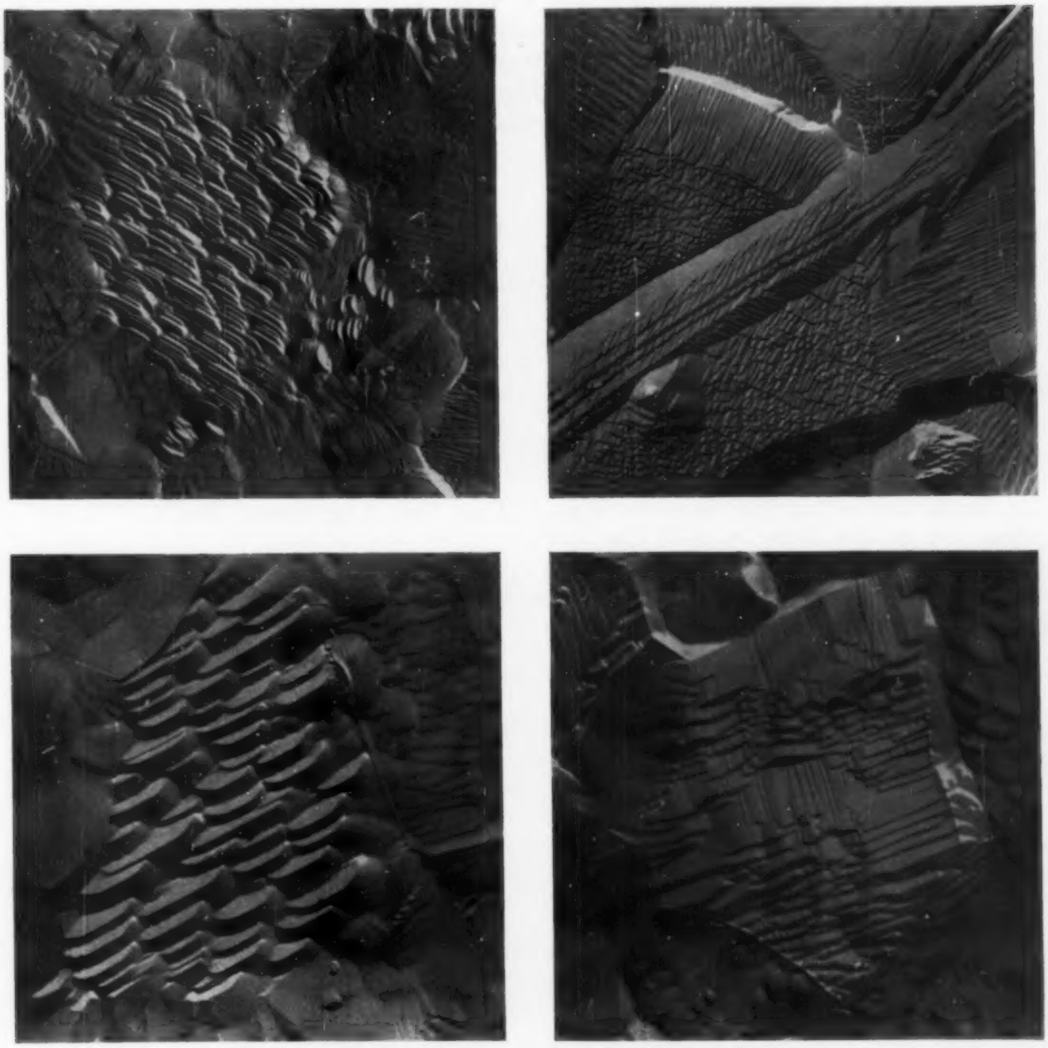
It is a thing that we have brought upon ourselves to live with, but let us stay well, well back from that awful brink!

*Head of the Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

Grand Prize

12th ⊜ Metallographic Exhibit

to T. K. BIERLEIN and B. MASTEL, Hanford Laboratories, Richland, Wash.



Electron Micrographs of Zircaloy-2

Nominal composition, 98.4% Zr, 1.4% Sn, 0.05% Ni, Fe, Cr. After vacuum annealing at 700° C. (1300° F.) the specimen was slowly cooled, the surface polished and "etched" by bombardment with krypton ions, the specimen being cathodic to a 4000-volt direct current.

Grains are clearly defined; different intragranular structures are revealed (possibly polygonized architecture in the hexagonal crystals). The engraving is half the size of the original exhibit, so the top two are reproduced at 2000 dia. and the bottom two at 4500 dia.

Critical Points...

BY THE EDITOR...

Doff Bonnets to Carnegie!

In 1932 an event of great importance (even to John R. Citizen) occurred in Pittsburgh. A handful of teachers at Carnegie Institute of Technology (Bob Mehl, Max Gensamer, Charley Barrett, Gerhard Derge, Cyril Wells and Fred Rhines) formed a group whose sole purpose was to find out why our metals are at once so much stronger than most substances found on earth yet also far weaker than their theoretical capabilities. It did not matter to these men that they were doing something new, that they had only meager equipment in a basement laboratory, that the depression (remember it?) prevented adequate financial support. They were young and brave.

Twenty-five years later several hundred industrialists, educators, civil servants and scientists from the English-speaking world gathered to congratulate these six men and the Carnegie Institute of Technology on this event and its aftermath. It was a notable milestone on the path which has led to the development of a real science of metals from an expanding art of metallurgy. Metallurgists have been joined by physicists, and so we find that other important American research laboratories are now doing much fundamental research in the physics of the solid state. (Physicists formerly handled easy things like gases and liquids.) Metals necessary for electronics, communications, high temperatures, atomic energy, would be missing were it not for this new science which was dimly foreshadowed when these men at Carnegie Institute of Technology moved aside some junk in a corner of a dark basement and started their work.

Planners frequently talk about "lead time" which passes between, say, the request for a faster bomber and its appearance on the flight line. How much thought is given to the "lead time" which must elapse between an experimenter's idea and a new high-temperature alloy fabricated in quantity? Congratulations to Mehl and his crew and to his Institution for having started so early, and having shortened the lead time in so many important ways!

Can You Use Some Tin?

In that same year, 1932, another group for another purpose started its studies in England – The Tin Research Institute, organized by producers of the metal in various countries with the intent of increasing consumption of their metal. This was a difficult task in one sense, since tin had been an article of commerce for thousands of years and long, long experience had shown what it is good for. In another sense it should have been easy, for it is a truism that the things we have known longest (such as bricklaying) we know the least about. Thus, the intervening years have been giving a partial answer to the question, "What can science do for such a material as tin?"

Four lines of activity have been followed by Ernest Hedges and his staff. First, to improve existing uses. (Here it was necessary to get into step with the change from the hot dip process for making tin plate to electrolytic tin coatings on sheet-strip. Solders, bearings, bronzes, pewter – all these could and have been improved.) Next, pay attention to new uses – and here electrolysis again plays its role in methods for the simultaneous deposition of proportionate amounts of tin and nickel for a hard bright coating, and tin and zinc for corrosion resistance and easy solder-

ing. Another new use is the heat treated aluminum-tin bearing with superior fatigue resistance. A third productive effort of the research staff is to attach tin to various organic hydrocarbons, forming new chemicals whose greatest use so far is for fungicides and pest control. Finally is the matter of substitutions, and in this field it has been found that wartime efforts to stretch out the amount of available tin have nearly always proven that a substitution or a reduction of time-tested proportions of tin runs into higher labor costs, more than outweighing any savings in the raw material.

The Tin Research Institute was viewed with considerable skepticism by many large users of tin in the early days, but this barrier was quickly broken down in wartime. Fruitful cooperation with industry throughout the free world is now the rule. The Institute's activities attest the fact that something is needed to bridge the gap between scientific investigations and industrial practice. This is sometimes called "applied research". More power to it!

A Generation's Progress in Steelmaking

In 1927 the Editor of *Metal Progress*, then with *Iron Age*, was asked to rewrite the article "Iron and Steel" for Encyclopedia Britannica, which he thought was quite an honor since it was to supercede one written at the turn of the century by Henry Marion Howe. Twelve years later he revised this and in "Critical Points" in November 1939 he listed the major additions or corrections as a gage of progress in that decade:

"Beneficiation of Lake Superior ores; desulphurization of pig iron with sodium carbonate; revival of bessemer steel for engineering purposes (fast machining); various items of openhearth practice such as *(a)* slag control, *(b)* grain size control, *(c)* American scrap and hot pig practice, *(d)* British continuous practice with little scrap; high frequency melting furnaces; continuous wide sheet mills and the great expansion in sheet uses. The section on alloy steels was entirely rewritten to systematize the subject, point out the trend to low alloys, controlled grain size and hardenability, and the rise of molybdenum. Extensive additions were also made on the heat and corrosion resisting steels, cobalt and molybdenum high speed steels, controlled atmospheres in heat treatment, localized heating with high frequency induced currents, on the nature of martensite and transitional microstructures, and the intermediate structures in quenched alloy steels."

Only recently this article, now to be called "Iron and Steel Industry", was again brought up to date. A similar listing of things which have been accomplished or given much study in the 18 years just past may again have more than passing interest:

New sources of ore and changes in blast furnace practice and pig iron treatment to cope with low-grade coke.

Pressurized blast furnaces and controlled humidity blast.

Direct reduction of iron ore by gas.

Oxygen in openhearth melting and in Linz-Donawitz vessels.

Low-nitrogen bessemer steel (blowing with low-nitrogen blast).

Electric steel cast into small ingots.

Continuous casting of slabs or billets.

Consumable electrode melting of alloy steels.

Vacuum melting or treatment before teeming.

Sound ingots and forgings (hydrogen flakes, inclusions, segregated alloy, transverse weakness),

Hot extruding with glass lubricant; back-extrusion cold.

Directional crystallization in silicon iron.

Fast annealing of strip-sheet.

Electrically welded pipe (overlooked in 1939).

Trend toward lower alloy, fewer engineering steels, and specification by hardenability bands.

Boron as an alloying element.

Great diversity in toolsteel compositions; metal-bonded hard carbides and oxides.

Controlled atmospheres for heat treatment, carbonitriding and carbon restoration.

Isothermal transformation, TTT curves, bainite, austempering, martempering.

The article, being entitled "Iron and Steel Industry" made slight mention of important things being included under other headings, such as physical metallurgy, foundry practice, fabrication operations, and the properties of carbon, alloy and high-alloy steels, all of which have of course made notable progress in recent years.

A Thought About Research (and Automation)

According to *The Frontier*, published by Armour Research Foundation, nearly half the visitors to the Chicago World's Fair in 1933 were earning a living from industries which were non-existent in 1893 when the Columbian Exposition was held in Chicago.

Science and People

By JOEL HUNTER

The metallurgical industries demand much more basic research and applied science if they are to produce metals in ever increasing volume and for more stringent requirements – despite inflated costs of labor and capital goods. This matter has especial urgency in this day of missiles and earth satellites. (A9)

IT IS NOT as a scientist that I am here, but as a person – one of the people to whom science is important. Science is important to all people because science is knowledge. Greater knowledge of the things surrounding him has worked progressively toward improvement of man's physical well-being. He has inherited the edifice of knowledge which has been painfully and slowly erected, tier on tier, over the centuries.

I have a claim of right to address you on this subject, not alone as a person – an individual whose life is affected by science – but as one of the managers of industry – which rests upon a foundation of science, though yet incompletely understood.

Only in comparatively recent times have advances in science influenced progress appreciably in the practical arts, and so started to change the lives of people. Things did not begin to happen until the 18th Century, with the beginnings of the industrial revolution. In the iron and steel industry, such milestones may be noted as Smeaton's improvement of blast furnaces, using coke for the production of iron; the invention of the crucible steel process from which, incidentally, my company takes its name; and Cort's puddling process for making malleable iron. The iron in the nails on the cross on Calvary and in the gun which shot the first Thanksgiving turkey in the Massachusetts Bay Colony were both made in essentially the same manner.

While the industrial revolution was in progress, science was advancing rapidly. The men of science and of industry were in touch with each other, yet the progress of the iron industry, and even the development of the steam engine, owed but little to the advancement of science . . .

It was not until the 20th Century that the steel industry began to recognize a need for the application of scientific principles to its problems . . . The basis for the science of metals had been laid earlier with the application of the Gibbs phase rule to metallic systems by Roozebloom, with an incipient understanding of the nature of phase transformations, and with Mattheissen's studies of electrical properties of alloy systems. A body of knowledge began to emerge identifiable as a coherent system. This shortly was combined with older industrial metallurgy, creating what is now a newly maturing and exceedingly active metallurgical science.

The final development, the organized and sustained pursuit of scientific knowledge directly by industrial companies through large groups of employee-scientists, came relatively late in steel . . . We now recognize the practical, dollars-and-cents value of greater scientific knowledge, but

Verbatim extracts from the principal address before the Annual Metal Awards Luncheon, Nov. 5, 1957, at the National Metal Congress and Exposition, Chicago.

Joel Hunter, President, Crucible Steel Co. of America

we have a long way to go. In 1956, less than 2% of all United States industrial research was done by *all* of the primary-metals industries. Only one-tenth of that small portion was in basic research.

And so, as we now move into the second half of the Twentieth Century, we find the scientist definitely and firmly established as an integral part of the primary-metals industries. I suggest that the dependence of these industries on science will grow larger rather than less in the future. A recent McGraw-Hill survey shows substantial increases in employment of scientists in the next two years in almost every industry. Significantly, the highest of any industrial category in this survey is iron and steel, with an expected increase of no less than 26% . . .

The steel industry is presented with a strong and continually mounting challenge. Of the several elements of this challenge, perhaps the most compelling is the extraordinarily rapid increase in production costs, particularly labor costs.

Inflation is a thief who robs everyone, but he takes more from some of us than from others. The industry employing large and heavy equipment, which costs a great deal to buy and lasts for a generation, is a special victim. It has, under these present conditions, no ready answer to the conundrum: where to get three or four times as much money to replace a worn-out mill as that mill cost.

Price inflation, coupled with the high-cost, long-lived equipment required in steelmaking, has furnished a compelling incentive to find a better way. If by spending $25,000 on a research project we can hope to obtain an increase in production equivalent to another $1,000,000 invested in mills or furnaces, it becomes a case of weighing the odds. We may wind up by doing both, but merely weighing the odds gives recognition to the possibility of research as a supplement – if not a substitute – for important capital expenditures. Speaking as one whose duties include raising capital funds for my employer, I can testify to a deep and abiding interest in a low-cost substitute for capital funds.

The problems of cost acceleration and capital deficiency are given added dimension by increasing demand. Not only must the steelmaker find ways to augment production to cover rising costs, but to keep pace with the correlative forces of population growth and increase in per capita usage. He is threatened increasingly with the competition of other materials, both metallic and otherwise. His position as the producer of the prime low-cost structural material is in danger . . .

Twice now, within the past few weeks the

whole world was jolted by the spectacular achievement of the scientists of Russia. In the creation of two new planetary bodies, however small and however temporary, science has again broken through a barrier – the barrier that confines mankind to this earth. The implications of this breakthrough are awe-inspiring, suggesting as they do that one day man himself may traverse the regions of outer space. But whether he goes in person or vicariously by the use of machinery designed to give him eyes and ears at such a vantage point, he has enormously increased his potential for knowledge of the planet on which he lives. With this, as with all knowledge, goes power – power to influence events on earth, to make war, perhaps, in even more horrible fashion than we have known, accustomed as we are to horror. Inhabitants of the western world are gravely ill at ease in the knowledge that this power at the moment is in the hands of those who do not think as we do. Whether we of the West have this power, too, I do not know. Perhaps no one knows the relative state of science, of which the satellite is the symbol, as between the East and the West . . .

In the decade which followed the first dreadful use of the atom bomb, the technology on which it rests has found uses for the improvement of mankind as well as his destruction. Today, in the United States, we find it necessary to spend the vast sum of 38 billion dollars a year for national defense. As a taxpayer and thus a contributor toward this fund, I do not object. In an earlier and simpler age, George Washington said: "To be prepared for war is one of the most effectual means of preserving peace."

We must have a police force. Yet 38 billion dollars is taken of our substance in one year, to return no income, to produce nothing, essentially to keep the peace by threatening the aggressor with annihilation. In contrast, in this country in 1956 we spent 7 billion dollars for research.

Let us say that all of this 7 billion dollars spent for research was for the ultimate purpose of improving man's material well-being – for making his life better and easier. Seven billion dollars for the improvement of mankind and 38 billion dollars for his destruction! A telling comment when the greatest peace-loving nation must put forth five times the effort to annihilate as it does to create . . .

As today's aircraft become more and more advanced, the pilot becomes more and more a spectator, sitting by while complex instruments, acting quicker than thought itself, do half a dozen jobs at once. And so we reach the present stage where even the spectator is no longer necessary. The very pilot is outmoded and we take him out of the plane altogether. We send a missile.

Is there a broader analogy here? Have we perfected the *things* of the world to such a state of art that our ability to direct and control them is in jeopardy?

A century ago Emerson said:

"Things are in the saddle,
And ride mankind."

Here is a challenge, indeed. We must know the meaning of our science. We must remember that science is for man and not man for science. However Frankensteinian our technology may become, the human mind is as capable of control as creation. The mind and spirit have no less a potential than the intellect as applied to technology.

There can be no control without understanding – understanding of our own work as it relates to the work of others – understanding of our science as it contributes to the lives of people – the destiny of man. We must work to cultivate and improve our understanding and comprehension. We say with the Old Testament prophet: "Wisdom is the principal thing; therefore get wisdom; and with all thy getting, get understanding." . . .

We have much to learn about this "Wonderful World of Metals". More than 80 of the presently known hundred-odd elements are metals; only about a third of these are currently of real importance. Nearly two-thirds of the metallic elements are frontier materials. And think of the possible alloying combinations and the things to learn about temperature and deformation! . . .

A world congress such as this will promote knowledge, but it can also serve to increase understanding. The larger perspective, the broader view gained from social and technical intercourse with men of different lands and races, is of great significance. Let us strive to get true understanding of our science and its meaning to ourselves and to other people. Let us remember that knowledge without understanding is hardly more than memory – a mere mechanical property. We must have understanding in the largest sense, a property of the mind and spirit, the unique possession of man. In being better scientists, let us not forget to be better men.

Motor Makers Discuss Aircraft Construction

*Reported by J. L. McCLOUD**

With the advent of strong sheet steels for airplane structures, dimensional tolerances, their machining, bonding and plating introduce new problems. Electrolytic grinding and milling, as well as metalizing in vacuum, are interesting and important innovations. (T24a, G24, K12, L17, L23, 17-7)

WHAT'S NEW, technically, in aeronautics? Well, the biggest things aren't new but they are continuing. Now-a-days all of us, as taxpayers, support airplane construction, but few realize how engineers and scientists get together to exchange ideas about how best to design and fabricate engines and the airframes they support and are supported by. This means that for the same airplane the costs go down – or rather, in this international race, our planes keep getting better but at a cost that doesn't grow as fast as their value does. Now that's the reason for technical engineering meetings and how everyone gains by them.

Another thing comes to mind, and that is how interrelated and overlapping these meetings are. The American Society for Metals holds a forum on metals and materials – but so also does the Society of Automotive Engineers, different (it is true) in detail and speakers, but the same in general theme. These modern forums are also well planned. When the subject concerns automobiles and trucks, certain company's engineers predominate; when it concerns airplanes we find men from other companies. Both industries are of such size that the meetings are almost run by platoons – just as in the system formerly used on a football field.

High-Temperature Sheet Materials

The first panel considered manufacturing techniques for high-temperature sheet materials – high-temperature meaning 600 to 1000° F.

Naturally we started with the strength-weight ratio at working temperatures. The conventional aluminum and magnesium alloys will do up to 350° F., a temperature raised 200° by the high-strength aluminum alloys. New, creep resistant magnesium alloys have a useful range from 850 to 800°, approximately equal to the titanium alloys and the precipitation hardened 17-7 Cr-Ni steels. Alloys high in nickel, chromium and cobalt (and perhaps some of the higher-alloyed precipitation hardenable stainless steels) can be applied in parts working up to about 1200° F.

Titanium – It was noted that in manufacturing titanium sheet 10 to 15% of the cost is for quality control of the raw materials, the vacuum melting operation, rolling into sheet, and fabrication. After briquetting the sponge and subsequent remelting and casting, the ingots are checked for solidity by sonic gages. Sheet is hot rolled and generally hand finished rather than strip rolled. The layer of oxygen-contaminated metal is removed from sheet by blasting, hot salt bath or nitric acid pickling. Gas pick-up is analyzed by high-vacuum methods. In heat treatment – heating, quenching and aging (tempering) – argon atmospheres are frequently used

*Consulting Editor, *Metal Progress*. Commentary on Society of Automotive Engineers' "National Aeronautic Meeting," Los Angeles, Sept. 30 to Oct. 5, 1957.

to prevent scaling. In quenching it is important to get the aluminum-vanadium alloys into the quench promptly (less than 10 sec.), but these techniques have been well worked out in the titanium industry.

Dimensions – The smoothness of titanium sheets is generally about 50 rms. and this too is being improved, much to the delight of aircraft designers. Belts used in finishing sheets by grinding have very short life when the 10 to 15% of the metal is removed. Wider belts are under way for wider strip and sheet.

Wider sheets are desired. In the future, continuous strip rather than single sheets will be produced. Stainless steels are now generally restricted to 48-in. widths (as contrasted to 98-in. for low-carbon steels). To produce a wide strip, still wider mills are required and the power to drive them is very large. The temperature of rolling (and plasticity) is naturally restricted by the induced metallurgical changes, so this controls the width to which these high-cost mills can be made. Gage control is solely in the strip mill, and end-to-end thickness tolerances are rather low. "Buckle" is difficult to control even by careful and time-consuming operations in four-high stands; Sendzimir planetary mills are said to be easier to adjust and can roll all the light gases, and have therefore been installed by several producers.

In making very light gages, annealing and pickling are the problem; producers which anneal in hydrogen can make stainless to 0.001 in.

Structural Damage in Simulated Tests by Martin Aircraft Co. Involving High Sound Intensities up to 160 Decibels. Courtesy Air Research and Development Command, U.S. Air Force

thick and 24 in. wide. In rolling the take-up reels are very powerful and some camber can be stretched out.

Significant savings in airplane weight could be made if wider sheets were available. (It is estimated it would take at least two years to install rolling mills for such sheet.) Aircraft designers are now demonstrating their need for such sheets by welding strip to 72 in. wide. Unfortunately the quantity required is in such small tonnage that steel mills are not hastening into production.

Since these new and improved metals are all quite expensive, a designer has to justify both material and fabrication and inspection costs. Sometimes lesser materials or composite designs may be the ultimate choice.

Quality Controls

Quality control, as related to manufacturing, is a subject equally interesting to metallurgists and to engineers. Process control (part of quality control) in fabricating 17-7 PH steels can sometimes go beyond practicability. To make lighter and stronger airplane structures, the quality must be controlled to a higher and higher degree. This relates to the platings, chemical coatings (such as anodizing) as well as complex heat treatments and precipitation hardenings. To make sure that the expected high values are obtained, manufacturers regularly run verification test pieces along with production work to determine the release to production.

Heat treatments may consist of transformation at 1450° F. followed by air cooling to 60° F. by water, refrigeration, then precipitation treatment at 1050° closely controlled as to temperature and time. Hardnesses of Rockwell C-40 to 45 and tensile yields of up to 200,000 psi. are obtained. While the steels are "stainless", there may be composition changes, such as carbon pick-up from tiny amounts of oil or tarnish from the salts of perspiration. Consequently clean cotton gloves are used by the workmen.

Another critical factor in quality control is size tolerance: 5% is usual for aluminum. Aircraft designers have been quoted as being willing to pay $30 per lb. of weight saved in an airplane. However it depends on whether it's a pound put on or a pound taken off. Just as this question is an "iffy" one, so is the value of process improvement and control by metallurgical laboratories, and at what exact level controls can be specified. Chemical analyses of the materials are becoming more difficult to

meet. Mechanical properties must also be measured at controlled rates of strain. This gets out into the plant in an effort to control strain hardening during forming in hydraulic presses over dies that are cooled.

So "Quality Control" is the department which sees that the design is met. At one extreme Quality Control may merely verify the acceptability of a random sample; at the other extreme they may certify that the manufacturing processes are suitable.

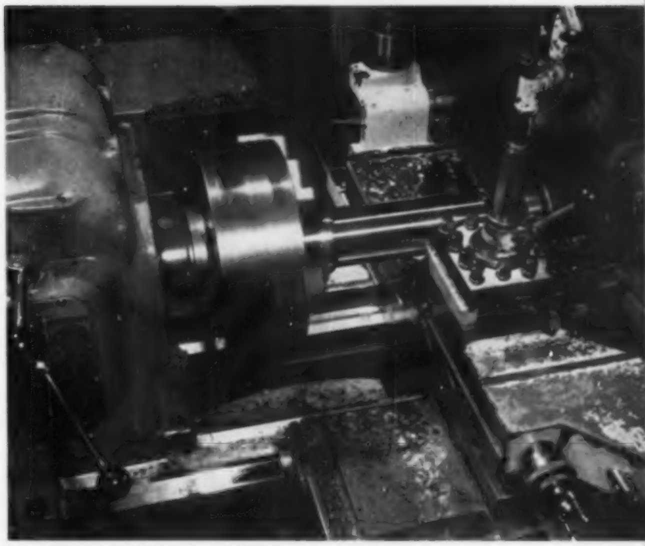
Tools are generally of standard types. Tools wear and use up some of the design tolerances. Then, too, the gages must be assigned tolerances themselves, although of much lesser amounts. Tools ordinarily have half and inspection gages one tenth the tolerances of production.

Machining High-Temperature Materials

The newest tools are ceramic. To focus attention on the needs, Col. Paul F. Nay of the U.S. Air Force described the probable requirements. They show how, in this changing world, the problem of high-temperature metals becomes more that of metal moving rather than removing. However, it seems that the metals which are strong at high temperatures are also hard to cut with conventional tools. Ceramic tools other than carbides have been given much attention. These are sintered aluminum oxide. While they don't beat sintered tungsten carbide, their value may lie in the event we are short of tungsten. So ceramics aren't apt to replace carbides but to supplement them.

For turning operations in rigid, vibration-free round and unscaled work they gave good account of themselves on either Type 410 or 347 stainless. While they cut all right when dry, the hot fine chips weld to the machined surfaces! A water soluble coolant eliminated this trouble. The chips and workpieces get hot but the tools don't. The nose radius of the tool has no effect on life and finish as long as the depth of cut is less than half the radius.

"Chemical milling", or the process of removing metal by selective chemical etching to produce intricate recessed patterns, has been described at length in *Metal Progress*. It is done by applying a masking adhesive which is cut and stripped away from areas to be cut away then immersing the work in a corrosive etchant. Finally the work is rinsed to kill the action, the part is completely demasked and then is ready for use. The process promotes lightweight integral construction, tapering of sheets, and intricate recessed patterns either with inside or outside to good tolerances. Cast surfaces come out smoother than originally. Titanium, steels (even stainless), aluminum and magnesium alloys are "Chem-milled".



High Surface Finish (45 Rms.) on Final Cut on Stainless Steel Bar Machined With ⅜-In. Aluminum Oxide Ceramic Inserts. 0.025-in. cut, 0.008-in. feed, cutting speed 505 ft. per min. Courtesy J. N. Willits, Ryan Aeronautical Co.

Refrigerated Coolants – An interesting idea about cutting fluids is to freeze them. Naturally problems arise, such as high viscosity at −40° F., freezing of water emulsions, and low chemical activity. A low tool temperature permits it to retain more strength and stay sharp longer. Then, too, when the cold material being cut becomes more brittle the chips are nicely broken up. This does not apply to most stainless steels, since they retain their toughness at the lowered temperature, but improved cutting resulted with S.A.E. 4130 and 4340.

Electrolytic grinding and milling is a new and especially interesting process with high alloys, and steels with tensile strengths upward of 200,000 psi. Electrolytic etching and abrasive lapping are concurrent, something like the preparation of a metallographic specimen. (Incidently the color of the etchant often discloses the composition of the workpiece, and so spots a mix-up in materials.)

The etchant is assisted by a low-voltage, high current passing between it and the piece. The lapping wheel is of metal with abrasive grains

embedded on its surface and protruding slightly. The electrolyte also acts as the coolant. Thus it is distinctly different from various spark, arc or electro-discharge machining methods.

It was said to be from five to 50 times as fast as conventional grinding, but its real utility is with hard and high-strength materials that conduct electricity – for example on stainless steel honeycomb where edge burrs are bothersome. It is preferable to make a single cut rather than several passes, provided only that there is sufficient electrical capacity so the attack occurs across the whole wheel. The workpiece is heated but slightly; grinding cracks do not occur. Form wheels of metal-bonded aluminum oxide may also be used.

The electrolyte rinses off with water but sometimes a remaining smut may require a rust remover. The fluid is really neutral, chemically, but is kept on the alkaline side to minimize any tendency to rust. It is nontoxic, and used until it gets dirty and then is discarded.

Metal Bonding; Sandwich Construction

Sandwich structures are being used to a substantial extent. The skins as well as the core may be 17-7 PH steel, the 6% V, 4% Al titanium alloy, or even high-nickel alloys such as Inconel "X" or Hastelloy R-235. The meat in the sandwich (core) is usually honeycombed.

For high-temperature service the problem is to get an adhesive that will stand the heat. In aluminum airplane parts it is done. In the 180 to 250° F. range organic polymers may give 2500-psi. lap shear strength. Tensile shear at 500° F., even after 200 hr. aging, is about 1200 psi., and this appears to be the present useful limit. The organo-metallics, like silicone, give 700 psi. tensile shear at 600° F., again with 200 hr. aging at the same temperature.

But the aircraft people have by-passed the 400 to 600° F. range and now are talking of planes and missiles operating in the range of 600 to 1000° F.

One airplane company is experimenting with a ceramic that gives 1500-psi. tensile shear at 800° F. after 200 hr. aging at this temperature. In manufacture the ceramic "glue" is applied as a thin slurry in several coats to about 8 mils thickness. (Other approaches are being studied – for instance, silver brazing of stainless steel honeycombs.) "Peeling strength" should be high for safe handling, and the ceramics are poorest in this respect. They haven't much resistance

Thin Stainless Steel Honeycomb Being Shaped by Anocut Electrolytic Grinding and Milling Without Objectionable Burrs. Courtesy of Twigg Industries, Inc.

to water, and the sandwiches are generally sealed on the edges.

These and other factors breed conservatism in aircraft designers. A sandwich isn't always the lightest. Nor is it always the cheapest; estimates run from 10% less costly to twice that of conventional construction, if the word "conventional" has much meaning in these days of rapid advance. The essential question is "How well is it stuck?" This is now satisfactorily answered in plants operating under strict process control.

It is said that up to 90% of some airframes are metal bonded. It seems a satisfactory solution to "sonic fatigue".

Plating Processes

That steels rust is too well known; that cadmium is an ideal self-sacrificing protector is likewise well known. However, cadmium electroplate invariably embrittles the steel it protects from corrosion.

This effect is most noticeable with steels of over 180,000-psi. strength. For such parts cadmium deposition from vapor is suggested – a method used for years for thin decorative forms.

Aluminizing is also done in vacuum, but it doesn't measure up as well in the salt spray test as cadmium. Nowadays metalizing chambers up to 60 in. in diameter and 60 in. deep are in use. With pressures as low as 0.5 micron of mercury, the cadmium readily exaporates from boats or crucibles placed near the heating elements and will quite uniformily coat the parts up to 0.0003 to 0.0005 in. Parts are usually held on rotating racks.

Cadmium adheres well to reasonably clean steel, except where it has been polished, so surfaces are usually blasted. This is true even where compound coatings are used. The "throwing power" is found to be better than with electroplating and the protection afforded equivalent or better. Post-processing chemical film treatments as well as organic coating may be used.

In other attacks on this problem of hydrogen embrittlement during electroplating, the embrittlement was indicated by angular bend tests on high-strength steel strip, baked at 375° F. for 8 hr. after plating. In the conventional cyanide baths, platings of standard thickness produced at 60 to 80 amp. per sq. ft. were less brittle than those plated at lower current densities which gave a brighter, denser plate. Apparently the hydrogen gets out more easily through the less dense cadmium. The gray soft cadmium has good adhesion and may even be wire brushed to a lustrous surface.

Fighter Landing Gear Forging, Metalized in Vacuum With 0.0005 In. Cadmium, and Its Condition After Salt Spray Exposure for 192 Hr. One-fifth actual size. Courtesy Lockheed Aircraft Corp.

Summary – Highlights of this important S.A.E. meeting might be interpreted as concern with heat treatments for the *newer* metals of aircraft construction.

These materials have brought new approaches to problems of metal removal. Ceramic tools, refrigerated coolants and electrolytic machining and grinding were described.

Metal bonding, quite new in itself, is already threatened because high service temperatures loosen the "glue". At least one important new ceramic bond is under study.

Vacum metalizing to avoid hydrogen embrittlement is a new adaptation of an older process of coating.

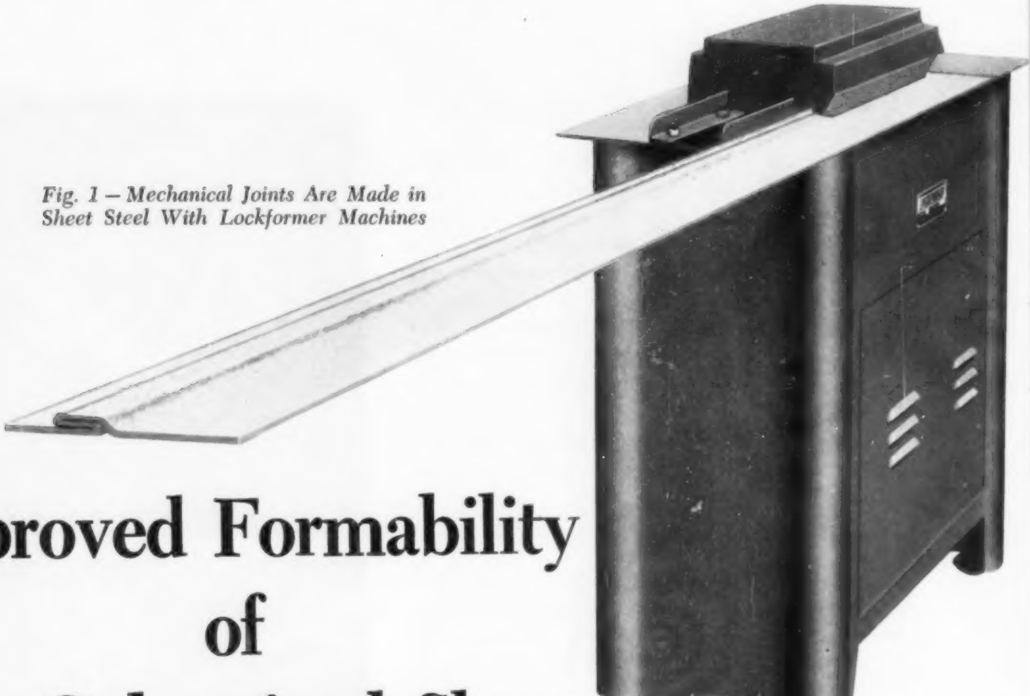


Fig. 1 – Mechanical Joints Are Made in Sheet Steel With Lockformer Machines

Improved Formability of Galvanized Sheet

*By J. R. KATTUS**

High-speed tensile tests, on both smooth and notched specimens, show significant differences between the properties of galvanized sheet that are acceptable and those that are susceptible to breakage in fabrication on a Lockformer machine. The notched ultimate strength provides the best measure of performance, increasing strength being indicative of increasing susceptibility to breakage. (Q23q, Q27a, 3-17; ST, *Zn*, 4-3)

GALVANIZED low-carbon steel sheet is used in large quantities in applications such as heating ducts, in which mechanical joints are made between adjacent sheets. Secure joints are formed by bending the lapped ends of the sheets together in a machine known as a Lockformer.

Steel manufacturers regularly test their galvanized sheet products in Lockformer machines to determine the suitability of each batch of material for such fabrication. In this test, samples of galvanized sheet are bent to the shape shown in Fig. 1. Because this type of bend is the same as bends formed in service joints, failures in the Lockformer test warrant the rejection of whole batches of sheet, which is quite costly.

Occasionally, large batches of galvanized sheet must be rejected because the base steel cracks at the apex of a Lockformer bend. Investigation of base-metal breakage in the Lockformer test has not led to a full understanding of the causes of the failure. Consequently, reliable methods of preventing failure or of preventing defective production runs have not been found.

A major obstacle to the determination of variables that control Lockformer performance is that no test shows quantitatively the difference

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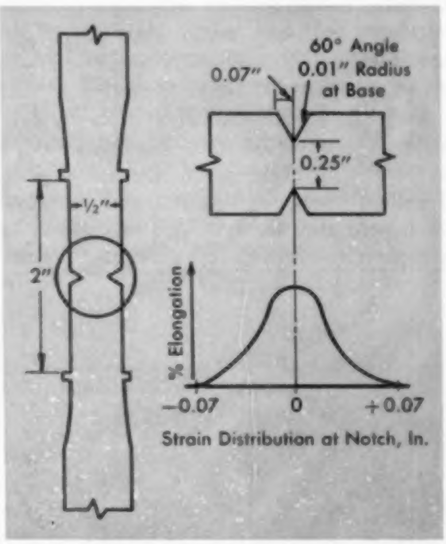
between acceptable and defective sheets. Lockformer tests themselves do not provide a measure of any of the properties of the sheet; they show only one of two things — the test sample cracks or it does not crack. Thus the relative effects of different compositions or production variables on Lockformer performance cannot be determined quantitatively. An investigation was undertaken, therefore, to develop a test in which some measureable property correlates quantitatively with Lockformer performance. Such a test in itself will not solve the problem of base-metal breakage, but it will provide a valuable tool to measure and evaluate the factors that control these failures.

The Problem

Although base-metal breakage occurs in tension in the Lockformer test, ordinary tensile tests do not show any abnormal characteristics in sheets that fail. Similar tensile properties are found both in good and in defective sheet. One possible reason for this anomaly is the fact that the metal in the Lockformer test is strained rapidly, whereas ordinary tensile tests are conducted at comparatively slow strain rates. Lockformer bends are produced in about 4 sec., but ordinary tensile tests require several minutes. Previous work at Southern Research Institute and elsewhere has shown that the tensile properties of most metals are significantly influenced by changes in strain rate.

Fig. 2 — Notched Tensile Specimen Loaded to Failure in 4 Sec. Showing Strain Distribution



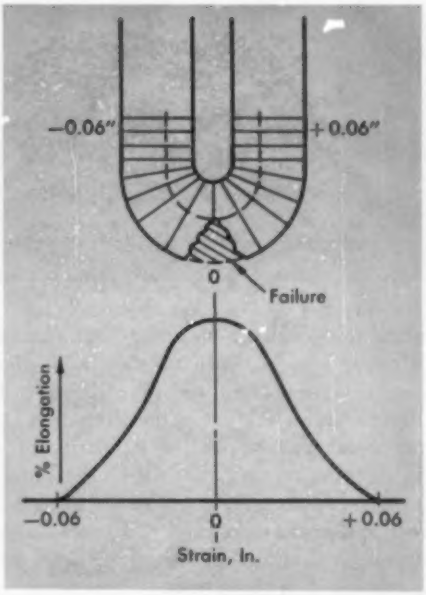


Fig. 3 — Strain Distribution at Surface of Bend in 20-Gage Sheet

Another significant variation from ordinary tensile tests is the localized nature of the loading in Lockformer bends. In tensile specimens, the load is evenly distributed over a 2-in. gage length, whereas only the short sections at the bends are affected in the Lockformer test. It was decided, therefore, to modify the ordinary tensile test to correspond more closely with Lockformer conditions.

Two separate modifications of the tensile test were evaluated for correlation with Lockformer performance. In the first modification, ordinary sheet-metal tensile specimens were used, but the strain rate was increased to 1.0 in. per in. per sec. — the maximum attainable with the existing testing machine. This strain rate, which produced failures in about 0.25 sec. in the tensile tests, is considerably faster than the rate in the Lockformer machine. It was reasoned, however, that if the effects of stain rate are the key to the development of a suitable test, the most sensiivity would be attained with the greatest possible increase in strain rate.

In the second modification, the tensile specimen and strain rate were designed to simulate as nearly as possible the conditions of stress and strain at the surface of sheet metal where the base metal breaks in the Lockformer test. The strain rate was adjusted to rupture the specimens in 4 sec., and the specimens were notched to

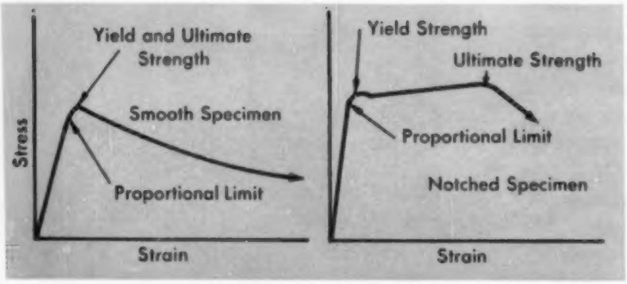


Fig. 4 – Stress-Strain Curves For Two Types of Modified Tensile Tests. Smooth specimen (left) loaded to failure in ¼ sec. Notched specimen (right) loaded to failure in 4 sec.

simulate the localized straining that occurs at Lockformer bends. Both notched and smooth specimens were of the dimensions shown in Fig. 2. Figure 3 is an analysis of the strain in a Lockformer bend and shows the similarity of this strain distribution and that about the notch in the notched specimens. Lugs at the gage points on both specimens were used to actuate a special extensometer designed to follow the rapid strain rates employed in these tests.

Finished sheet products tested were all 20-gage, annealed and galvanized, and analyzed approximately 0.06% C, 0.32% Mn, 0.012% P, 0.27% S, 0.009% Si, 0.024% Cu. Prior to testing, the galvanizing was removed in concentrated hydrochloric acid, which contained a small amount of antimony trioxide to inhibit attack on the steel. This was done so that Lockformer performance could be correlated with the properties of the base metal alone. Later a number of tests were carried out on samples taken at the hot strip mill, which is an intermediate stage of production with the sheet about 0.10 in. thick.

The sheet and hot strip were sampled at random. No more than two samples, representing the head and tail, were taken from a single coil at the hot strip mill or finishing lines.

Figure 4 shows typical stress-strain curves for the two types of modified tensile tests. The curves for smooth specimens tested at a rapid strain rate differ from the curves normally obtained with slower rates of loading in that the ultimate load in the rapid tests corresponds with the yield point and the load decreases continuously with further straining. The curves for the notched specimens resemble ordinary stress-strain curves for low-carbon sheet except that the total elongation is considerably less in the notched specimens.

Strain distribution about the notches was analyzed by the photo-grid process. The total percent elongations obtained for various gage lengths centered at the notch were plotted for both acceptable and rejected sheet. Data for both curves represent the average of 20 tests on different sheet. At all gage lengths, the elongation of the acceptable sheet averaged higher than that of the defective sheet. A gage length of 0.4 in. was arbitrarily chosen for subsequent notched tests.

Evaluation of Tests

In evaluating modified tensile tests as measures of Lockformer performance, 40 random samples of 20-gage annealed and galvanized sheet that had passed the Lockformer test were obtained. Forty samples were also obtained from sheets that had failed. All samples were taken immediately adjacent to areas that had been subjected to the Lockformer test. Half of the samples of each type were machined into smooth tensile specimens and the remainder into notched specimens.

Tensile tests were then run and the results were treated statistically. The high-speed tensile properties of the acceptable and defective

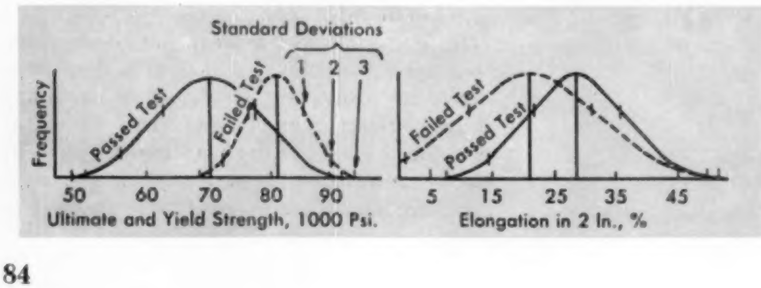


Fig. 5 – Frequency Distribution Curves for Properties of Smooth Specimens

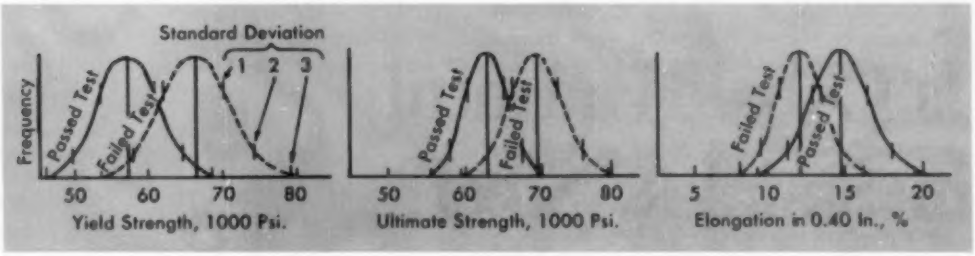


Fig. 6 – Frequency Distribution Curves for Properties of Notched Specimens

sheet are compared in Fig. 5 and 6, which show the normal frequency distribution curves for the properties of smooth and of notched specimens respectively. Each curve is based upon the average property value and the calculated standard deviation of 20 tests. Two other statistical values, the coefficient of variation and the "T" value, were used in comparing the properties of samples that passed with those that failed, as shown in the table. The coefficient of variation, which is expressed as a percentage, is a measure of the scatter of a variable about its mean. The T values, which are determined by dividing the difference of the means of two groups of data by the standard error of difference, provide a measure of the probability that there is a significant difference between the two groups – the higher the T value the greater the probability of a significant difference.

Results of high-speed tensile tests on smooth specimens (Fig. 5) show that samples failing the test had higher strength and lower ductility than those that passed. The T values of 3.48 and 2.15 (see table) show that the probability is only 5 in 1000 that the difference in strength occurred by chance and only 5 in 100 that the difference in ductility is a chance occurrence. Thus, it is almost certain that these tests show significant differences between groups of samples of sheet steel with different Lockformer characteristics. Because of the rather high coefficients of variation for some of the properties, however, the distribution curves for both strength and ductility overlap considerably.

Statistical Values for Properties of Samples

	Coefficient of Variation		T Value
	Passed	Failed	
Smooth specimens			
Ultimate and yield	10.5%	5.3%	3.48
Elongation	24.3	47.5	2.15
Notched specimens			
Yield strength	6.69	6.42	7.38
Ultimate strength	3.91	4.81	7.52
Elongation	11.93	11.44	5.40

Defective samples (Fig. 6) also had higher strength and lower ductility than the acceptable samples in the notched tensile tests. Furthermore, the T values are considerably higher than for the smooth specimens. These high T values indicate a virtual impossibility that the difference in notched tensile properties between acceptable and defective sheet occurred by chance. It is apparent from the smaller amount of overlapping of the distribution curves that the notched tests showed a more distinct difference between the acceptable and defective sheet than did the tests on smooth specimens.

Of all the comparative properties that were determined, the highest T values and lowest coefficients of variation were obtained for the ultimate strength of notched specimens. These results indicate that of all the properties investigated notched ultimate strength is the most reliable and precise measure of Lockformer performance. For subsequent investigations, therefore, notched ultimate strength will be used to determine quantitatively the relative effects of different variables on the Lockformer performance of sheet steel. Increasing strength will be indicative of increasing tendency for base metal-breakage.

As a further check, notched ultimate strength was determined on 40 samples of hot strip and corresponding samples of the same material after it had been fabricated into annealed and galvanized sheet. Half of the samples came from a production run during which no failures were experienced in the Lockformer test, and the other half were taken at a time when breakage was found in 40% of the tests. Comparisons for the annealed and galvanized samples are consistent with the previous findings; the group that contained 40% defective (*Continued on p.* 140)

Is Cobalt Harmful in Stainless Steel?

*By JOSEPH R. LANE**

In certain nuclear applications where neutron absorption converts the element into cobalt-60, stainless steels containing cobalt could become dangerous radiation sources. (P18h, 2-10; SS, *Co*, 2-17)

NORMALLY cobalt is present in small amounts as an impurity in the nickel content of austenitic stainless steel. In most applications of stainless steel, residual cobalt is of no consequence. It can be objectionable, however, in steels used in nuclear reactors.

When subjected to neutron bombardment in a reactor, an atom of natural cobalt can absorb a neutron and be thereby converted to a new isotope, cobalt-60. This isotope is unstable, and decays, with a half-life of 5.2 years, by the emission of gamma rays. When a reactor is shut down, the activated cobalt continues to give off its radiation. Unfortunately, the radiation is both intense and long-lived. Once equipment containing cobalt has been exposed to radiation, an extended "cooling off" period may be required before it can be approached safely. In addition, cobalt has an absorption cross section for thermal neutrons of 34.8 compared to 4.5 for nickel, and this could be undesirable where neutron economy is important. However, the presence of cobalt in the usual small amount raises the neutron cross section value by less than 1%. The trouble which cobalt causes is principally one of activation of a long-lived isotope, and not one of neutron absorption.

Whether cobalt is objectionable depends on the use of the steel in the reactor and on the reactor design as much as on the amount of cobalt present. For example, fuel elements jacketed in stainless steel would be "hot" from fission products, and would normally be handled remotely. A little cobalt might not matter. Or the reactor might utilize stellite control rods (which contain cobalt); this cobalt would be activated, and a small amount of additional cobalt would make little difference. On the other hand, cobalt in the stainless steel of a nuclear-powered airplane would be highly objectionable, since it would irradiate the airplane and its surroundings even after the reactor was removed.

The problem is recognized, and can be solved merely by using highly purified nickel. Normal practice utilizes nickel oxide sinter, which usually has an average cobalt content of about 0.7%. Electrolytic nickel contains just under 0.1% cobalt. Nickel free from cobalt can be obtained by using the Mond process, but the supply of such nickel is limited. The above figures apply to nickel supplied by the International Nickel Co. Cuban nickel might run higher in cobalt. The specifications for nickel acquired for stockpiling by the General Services Administration from the Nicaro property allow for a cobalt content as high as 1% in the nickel oxide sinter.

To satisfy the demand for materials to be used in nuclear environments, two grades have been established which are variants of the popular Type 347. One of these is 348, which is low in tantalum, a neutron absorber. The second is Type 349, also low in tantalum, and in cobalt.

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Type 349 has not yet been accepted as a standard grade by A.I.S.I. The general composition of all three is shown below, together with variations for each.

Carbon, max.	0.08%
Manganese, max.	2.00
Silicon, max.	1.00
Chromium	17-19
Nickel	9-13 in 347 and 348 9-12 in 349
Columbium plus tantalum	10 × C, min.
Tantalum	0.10 max. in 348 10% of Cb, max. in 349
Cobalt	0.20 max in 349

As consumption increases, there will probably be a demand for low-cobalt versions of other grades – Type 304 for example. If the demand were to prove adequate to establish a separate grade, the user should expect a price premium of slightly over 10%.

This problem of cobalt in nickel will tend to become more rather than less pressing as the production of Cuban nickel increases. In addition to the Nicaro operation (the Cuban Nickel Co.) the Freeport Sulphur Co. is developing a deposit in nearby Moa Bay and a plant for the extraction of the contained nickel.

Gamma radiation alone, such as from an X-ray source, has no effect on cobalt. Therefore, low-cobalt stainless steel is needed only for applications where neutrons are present, such as inside a reactor.

Book Review...

High-Temperature Studies in Handbook Style

*Reviewed by BRUCE A. ROGERS**

HIGH TEMPERATURE TECHNOLOGY, Edited by I. E. Campbell, John Wiley & Sons, Inc., New York, 1956. 526 p. $15.00.

HERE is a book the value of which can scarcely be questioned. It contains much information that previously existed only in journal articles and technical reports. Furthermore, it lists many valuable references in which the reader can find additional details. Although the book is not cheap it probably would be more expensive if the work of its 35 contributors had not been sponsored by their own organizations.

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The region of knowledge covered by "High Temperature Technology" is so extensive that it probably is beyond the experience of any individual. Hence, the inherent shortcomings of a contributed and edited book probably are less important than the deficiencies in knowledge of a single author.

Probably, also, the book supplies more information than any one person is likely to need. Among people who can profit by this book are those who work with gas turbines, jet propulsion equipment and missiles. It is of value also to those who deal with the high melting and easily oxidized metals and, accordingly, must work with high vacuums and inert protective gasses. It would be of even greater value to this group if it contained more about vacuum equipment. Metallurgists in the more standard activities probably will consult the volume only occasionally.

For the most part, "High Temperature Technology" is written in handbook style; that is, it

supplies useful information but gives relatively little theoretical explanation. As might be anticipated, the balance between information and explanation differs from contributor to contributor. Aside from an introductory chapter the book is neatly divided into three parts covering materials, methods and measurements.

Under "Materials", the various contributors cover the metals, several of the important refractory compounds, carbon and graphite, and the cermets. All of the metals except tungsten, molybdenum, tantalum and columbium are eliminated as lacking useful properties above 1500° C. (2730° F.). The section on oxides is relatively extensive. It includes thermodynamic data, detailed information on the physical and mechanical properties at high temperature of both simple and complex oxides, and some information on the preparation of refractory products. The relatively extensive treatment of carbon and graphite presents an analysis of the possibilities and limitations of these substances. The sections on the production and properties of the carbides, borides, silicides, nitrides, and sulphides contain much useful knowledge, although they are shorter than the one on oxides. This is true, probably, because these substances have not received such extensive study. A section on the history, production, and properties of cermets closes this part.

The part on "Methods," opens with an informative section on the mechanism of sintering that would fit at least equally well in the previous part. From this point on, it is concerned with furnaces for operation at high temperature. Among the interesting types is one in which the heating unit is a split tungsten tube capable of operation above 3000° C. (5500° F.). It is useful for quenching specimens from a high temperature. In another unusual resistor-type furnace, capable of operation above 2000° C. (3500° F.), the heating elements are made of thorium oxide to which 5 to 15% of rare earth oxides have been added. The use of induction heating for furnaces, for quenching treatments and for hot pressing is also described. The section on arc furnaces is devoted primarily to production equipment and is relatively detailed. It describes standard commercial arc furnaces and also the water-cooled copper crucible, consumable electrode and non-consumable electrode types that require inert gas atmospheres. The final sections in this part are devoted to rather too-condensed summaries of information on solar furnaces and the electronic torch.

The last part of the book is devoted to measurements of temperature itself and to the physical and mechanical properties of materials at high temperature. The measurement of temperature by thermocouples and by optical pyrometer has a good balance between theory and practice. This section also contains a review of special thermocouple materials for very high temperatures. It closes with an exposition of "an absolute noise thermometer". Measurements of physical and mechanical properties have been concerned mainly with ceramic substances. Also, since such work is relatively new, much attention is given to the equipment itself. Apparatus for making tensile, torsion, creep, and hardness tests is described in detail. The high-temperature physical properties studied are thermal conductivity, thermal expansion, electrical resistivity, and vapor pressure. Closing the sections on physical properties is an analysis of failure by thermal shock.

The last two sections are on high-temperature microscopy and high-temperature X-ray diffraction measurement. The former will be of relatively little interest to metallurgists since it relates almost entirely to refractories and omits reference to a number of furnaces used in metallurgical investigations, at least one of which permits observations at 30 to 60 diameters at temperatures above 2700° F. The report on the high-temperature X-ray covers the field well and has an excellent list of references, but it is condensed to an undesirable degree. Unfortunately, this section was written before the appearance of a publication on a useful adaptation by P. Chiotto of a Geiger counter X-ray diffractometer for high-temperature studies.

No book review is complete without a complaint department. In some instances, this is the part in which the reviewer appears to have had his heart in his work most thoroughly. However, "High Temperature Technology" averages out very well indeed. Besides the incidental comments already made, few statements of a critical nature appear appropriate.

A few misstatements or vague or ambiguous statements were noted, and in some instances too much knowledge on the part of the average reader was assumed. For example, probably not many metallurgists would grasp the distinction between a "melting furnace" and a "high-temperature arc furnace".

As a final statement, one may say that "High Temperature Technology" is a very handy book to have around.

A New Record-Keeping System for Metallographic Laboratories

*By J. R. DRIEAR**

A simple numbering method for photographs, specimens and pertinent information about laboratory investigations keeps them from losing their identities. (M general, A9g)

QUESTION: Why should I be interested in a new record-keeping system for my metallographic laboratory?

Answer: You shouldn't unless you're interested in cutting down confusion and making it easy to lay your hands on information, photos, and specimens in a hurry. One thing more – although this system was developed for use in a metallographic laboratory, the principles are adaptable to many other service-performing organizations.

Q: When did you dream this up – last night?

A: Not by a long shot. This system has been in daily use for more than two years in a laboratory doing everything from customer service work to applied research. And I might add, it works fine.

Q: What's so different about this system?

A: This system keys together all items generated by a particular work request. Included are parts, mounted specimens, photographs, photomicrographs, and the final report covering the work done.

Q: So how does this differ from systems ordinarily used in metallurgical laboratories?

A: In many laboratories, work requests are numbered consecutively, the mounted specimens are numbered consecutively and so are photos and photomicros. Of course, all start out together but don't stay together long because there may be more than one photomicro for each mounted specimen and there probably are more than one mounted specimen per request. Generally, the reports describing the work done and the results obtained have still another series of numbers. All these items can be traced back and correlated one to another. But, the confusion developed in finding, for example, that specimen 1842 is related to photo 2223 on report P-186 reminds a person of a mass Bingo game at a country fair.

Q: What keys all items together in this new system of yours?

A: A request number.

Q: Where does this come from?

A: Probably the best way to explain this is to show you a work request. This we call a "Request for Metallurgical Service" (Fig. 1). As indicated, the person desiring metallurgical service fills out this request in duplicate and brings or sends it, with the parts to be examined, to the metallurgical laboratory.

Q: Now, about the request number?

A: Hold your horses, I'm getting to that. When the request is received at the metallurgical laboratory, it is given a sequential number taken from a log book we call a Request Book. A page from this book, Fig. 2, will contain pertinent data about ten different requests when it is filled in. In the page shown here, the next available number is 33-C. This number will be assigned to the next incoming request. The number will be put on both sheets in the box reserved for metallurgical laboratory use.

Q: What happens to the duplicate sheet?

A: It is returned to the person requesting the service so he will know what number the work is being done under.

Q: I suppose if he wants to determine how his work is coming along he has to refer to the request number?

A: It helps but is not necessary. When a

*Supervisor, Metallurgical Laboratory, Eaton Mfg. Co., Detroit.

page in the request book has been completed, the request numbers are entered in cross card files. One of these files is arranged by material; the other by customer. Typical cards from each file, Fig. 3, show the request numbers concerning that particular item and aid immensely in tracking down request numbers quickly.

Q: Your request numbers have both figures and letters in them. What's this for – just to be mysterious?

A: Nope, they're useful. The letter is a code for the year. In our system, 1955 was A; 1956 was B; and 1957 is C. The number is a sequential number starting over each year with 1.

Q: Why do you show the year (in code yet) in your request number when the date shows plainly on the request sheet?

A: This is getting ahead of the story, but it's probably just as well. The request number shows up on parts and mounted specimens. We hold parts and specimens for two years and then throw them out. The code greatly simplifies the task of housecleaning. And besides, starting the numbers over each year makes smaller numbers to deal with.

Q: Okay. We left the request and the parts just as they came into the laboratory and after they had the request number affixed. I suppose the request and parts then go to the person who's to do the work?

A: Right. After consultation with the engineer or supervisor to make sure he understands what is to be done, the technician takes over. His first step is to stamp or mark or tag all parts with the request number.

Q: Suppose he had a handful of buckshot; what then?

A: This is the place for cloth mailing bags with tags attached. The tag is a fine place for the request number.

Q: Touché! Now what?

A: Now seems to be the time to explain the rest of the system. Take for example the work done under request 33-C. If a section is cut out of the part and mounted in bakelite, in preparation for polishing and etching, it is marked with a number like this: 33-C-1.

The 33-C, of course, signifies the request number and the 1 signifies that this is the first specimen made under this request. The second specimen would be marked 33-C-2; the third 33-C-3, etc.

Q: Suppose I don't mount the specimen in bakelite?

A: Mark it with its number just as if it were a bakelite mount.

Q: Okay. Say I take a photomicrograph of the specimen marked 33-C-1, what then?

A: Well, the negative obtained would be marked 33-C-1-1, showing that this was the first photomicrograph you had taken of mount 33-C-1.

Q: Now suppose I take another photomicro at a different magnification of the same specimen, would it be marked 33-C-1-2?

A: Right as rain! This number would indicate the second photo taken of specimen 33-C-1.

Q: Now then, a number like 33-C-3-2 on a photomicro would indicate that it was the second micro taken on the third specimen prepared under request 33-C. Right?

A: Right again!

Q: Here's where your system is going to fall down. Suppose I don't cut up the part but photograph it whole. I don't have a specimen number so what number do I put on the photo of the part?

A: Your question is easy to answer. You forgot one thing – that this system has had the bugs shaken out of it in two years of actual use. In this case, since there is no specimen number we put a zero in the specimen number place. The photo number would be 33-C-0-1, indicating that this was the first

Fig. 1 – Work Request Sheet

Forward Original and
1 copy with parts to
Met. Lab.

REQUEST FOR METALLURGICAL SERVICE
Project No. ______

For Met. Lab. use only:
Request No. ______
Work being
done by ______
Date Started ______
Date Completed ______

PART
Part Description, ______
No. Pieces Submitted: ______ Print No. ______
Material, (if different from print) ______

HISTORY
Obtained from, (Customer–Co. & Div.) ______
Part Operation History:

Part Metallurgical History, (if different from print) (Please include time, temp. atomsphere, etc.)

OBJECT OF INVESTIGATION
(Please attach any helpful sketches)
Find Out:

Special instructions:

Photos & Photo Micrographs Needed: ______
Requested by: ______ Phone No. ______ Date ______

photo taken of a whole piece under request 33-C.

Q: Going back to the mounted specimens. How do you know the identity and heat treatment of the particular specimen in mount number 33-C-6, for example?

A: At the specimen mounting press, we have a log book which has in it, on every other page, the request numbers in sequence, each followed by ten blank lines. While the mount is being made, the mount number, material, heat treatment and whether it is a logitudinal or cross-section specimen are entered under the appropriate request number in this log book. Where more than ten specimens are mounted under a request number, the facing blank page in the log book is used.

Request Number	Part	Material	Customer	Entered by	Work by	Requested by	Date Requested	Date Reported
31-C	Spring	SAE 5155	Grasshopper, Inc.	I.M.Boss	J.Grind	Letts Rush	1-10-57	1-16-57
32-C	Wrist pin gear	SAE 52100	Pivel Crank Company	I.M.Boss	P.Snap	N.A.Hurry	1-11-57	1-19-57
33-C								
34-C								
35-C								
36-C								
37-C								
38-C								
39-C								
40-C								

Fig. 2 – Sample Page From Work Request Book

Q: Then to identify a homeless specimen, all one need do is to look it up in the log book at the mounting press?

A: Correct. However, in addition to the log book entries, a brief description is usually written on the bakelite mount itself with a vibrating pencil. This cuts down on stray specimens.

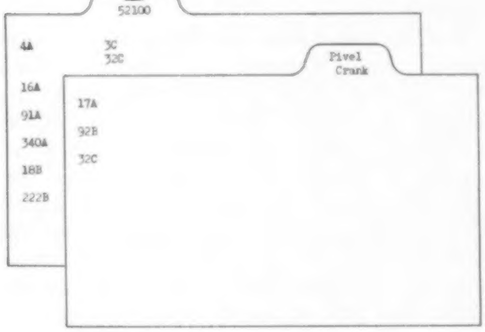
Q: There's nothing unique about writing on the bakelite mount. A lot of laboratories do that.

A: Agreed.

Q: Let's assume that all the work has been done under request number 33-C and the report has been written. How do you number the report?

A: Simple enough. We just call it Report 33-C. And there you are. Parts, specimens, photos and the final report all tied together and to the original request by the request number.

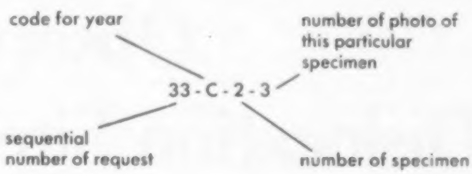
Fig. 3 – Typical Cross-File Cards. Card at left is from the material file; at right from the customer file



Q: When the report has been issued what happens to the original request?

A: It is filed (by request numbeı) and to it are attached any rough data sheets produced during the work as well as a copy of the final report. One thing more – the date on which the report is issued is entered in the appropriate column in the Request Book to complete the cycle.

Q: Let me see if I have this straight. This system can be summarized by a sketch like this:



A: That's it.

Q: One final question. How do you handle photo numbers in your reports?

A: We show them to the right of each picture along with the magnification and the etch, if any. By the way, since the report number is part of the photo number this is a handy way of telling which sheets of mounted photos go with what reports. Well, what do you think of the system?

Q: It looks good.

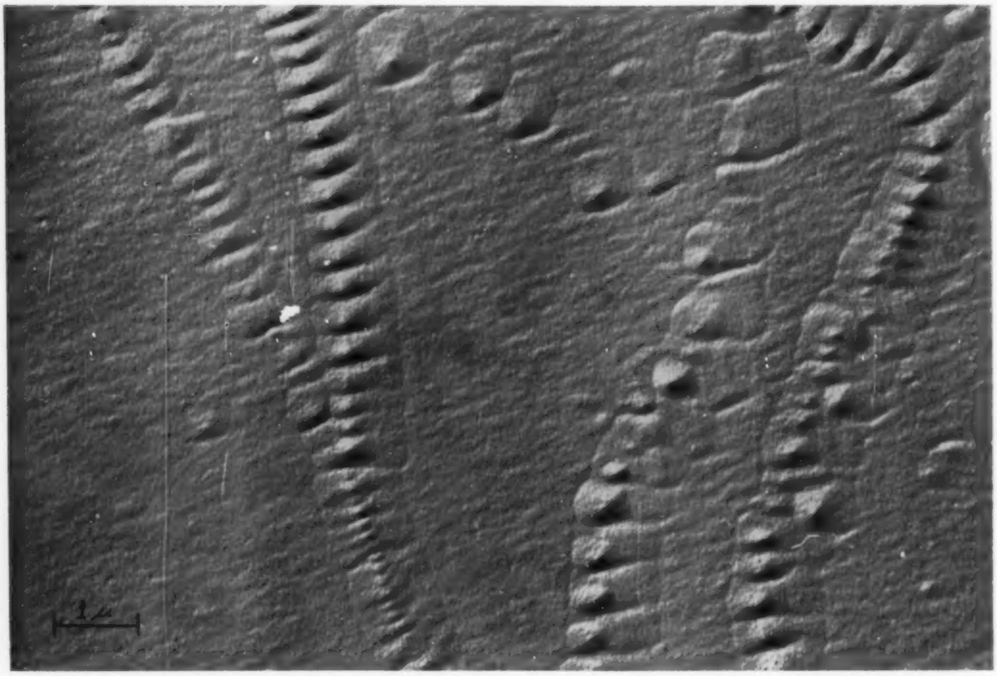
A: Do you think you'd like to adopt it?

Q: No.

A: Why?

Q: Because I'm being transferred to sales next month and someone else is taking my place in the laboratory.

A: Omigosh!



Electron Micrograph at High Magnification Showing Regularly Spaced Etch Pits Along Sub-Boundaries in High-Purity Iron, and Close Spacing in "Stem" as Compared to "Branches"

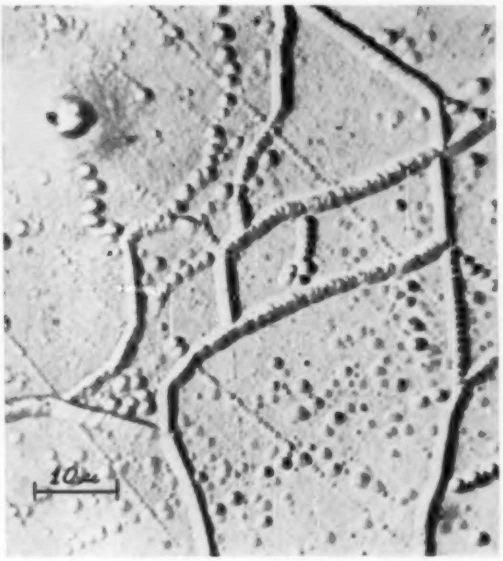
Observation of Dislocation Sites in Iron

*By F. W. C. BOSWELL**

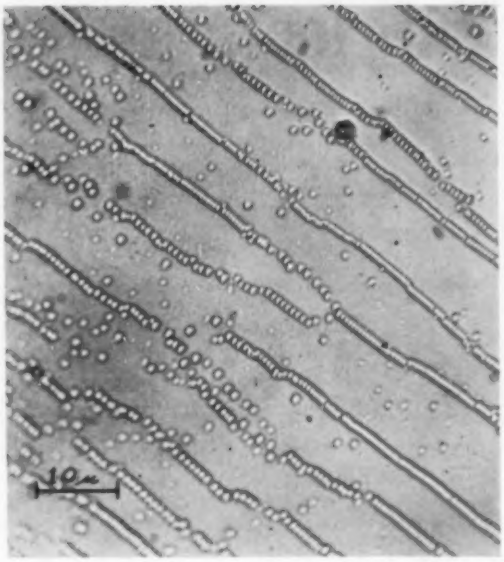
ETCH PITS at dislocation sites in several different materials, including some metals, have been reported by a number of investigators. Such observations have proven to be useful in studying the arrangement and motions of dislocations in crystals. The etch pits on iron, which are believed to be associated with individual edge dislocations, have recently been investigated by the author, and the technique and conditions under which these pits are formed are briefly reported here.

The work was done on high-purity, vacuum melted iron – "Ferrovac R", obtained from Vacuum Metals Corp. of Cambridge, Mass. Its analysis in weight percent was as follows: <0.01% C, 0.004% O_2, 0.001% N_2, 0.03% Ni, 0.007% Si, <0.005% H_2, <0.003% S, other impurities <0.001%. Specimens were electropolished in chromic-acetic acid according to the method described by C. E. Morris in *Metal Progress*, November 1949, p. 697, and immediately etched according to the following sequence:

*Senior Scientific Officer, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Ont., Canada. Published by permission of the director.



Regularly Spaced Etch Pits Along Sub-Boundaries in Recrystallized High-Purity Iron



Regularly Spaced Etch Pits Along Low-Angle Boundaries Lying Normal to the Slip Direction in a Bent and Annealed High-Purity Iron Single Crystal

1. Etch in 1% nitric acid in ethanol for 1 min.
2. Rinse in methanol.
3. Etch in freshly made 0.5% picric acid in methanol for 5 min. (agitate gently during this etching).
4. Rinse and dry.

So far, pits have been observed at dislocations only in specimens slowly cooled from between 750 and 850° C. (1375 to 1550° F.). It appears probable that some segregation of solute is necessary before the highly selective etching process can occur.

The view at top left on this page shows a substructure observed in a small percentage of the grains of a recrystallized specimen. The boundaries are closely related to the well-known "veining" structure of ferrite. Some of the sub-boundaries appear as grooves, whereas others are seen to be made up of regularly spaced pits similar to those boundaries in germanium observed by Vogel and reported in *Acta Metallurgica*, 1955, p. 245.

Another array of sub-boundaries is shown at higher magnification in the electron micrograph at the head of this article. Each pit is seen to consist of a shallow depressed region about 1 micron across with a small, sharply depressed region near the center. The resolution of the etching method is such that pits spaced only 0.1 micron apart are quite distinct. It may be noted that the density of pits along the lower branch of the sub-boundary at the left of this view is nearly equal to the sum of the densities of the pits in the two upper branches. This variation in pit spacing is compatible with theoretical predictions of the dislocation densities along branched tilt boundaries. However, with polycrystalline specimens it is not feasible to prove that each pit corresponds to only one dislocation, since the orientations of the observed surface and the dislocation lines are not known.

To establish quantitatively the relationship between the pits and dislocation sites, experiments were carried out in which oriented single crystals of iron were bent and annealed so as to form low-angle sub-boundaries composed of edge dislocations. The third figure is an example. The pits are aligned along parallel low-angle sub-boundaries which are normal to the active slip plane.

From these experiments, briefly reported, one can show that the pits do form at the points of emergence of *individual* edge dislocations.

This technique for observing edge dislocations in iron should lead to the direct experimental investigation of dislocation interactions in this metal. The method should also be of use in the study of the initial stages of the oxidation of iron, a phenomenon wherein the distribution of lattice imperfections is an important factor.

Fabricating Techniques for Jewelry

*By RALPH H. ATKINSON**

Blanking, coining, stamping and pressing are the methods most used for producing jewelry shapes. These, plus soldering and finishing, are the basis of the manufacturing jeweler's craft.
(G general, K7, L general, T9s; 17-7; EG-c)

MOST MELTING AND CASTING of precious metals for conversion into wrought form is done by refiners because few jewelry manufacturing plants are sufficiently large to make such operations economic. The exceptions are gold and silver because equipment for melting these metals is simple and inexpensive compared with that for platinum and palladium. Refiners' production costs are lower because their sales to jewelry manufacturers are only part (from one-third to one-quarter) of their total sales of fabricated precious metals. The refiner also has an advantage in being able to handle the valuable scrap promptly and economically.

Silver and gold alloys are melted in crucible furnaces, which can be heated by gas, oil or electricity. Some refineries also use induction furnaces for the production melting of gold. A charcoal cover is used when melting silver and the binary gold-copper alloys. Phosphor-copper is probably the most common deoxidizing agent for gold and silver; if gold alloys contain 1% zinc or more, no additional deoxidizer should be necessary. Melt sizes are approximately 1000 oz. for silver and 100 to 150 oz. for gold.

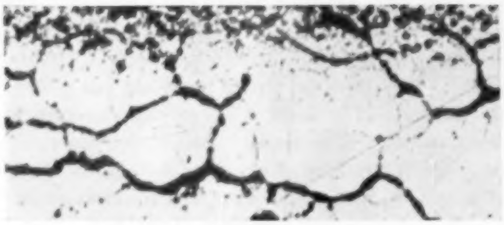
Production melting of platinum was done with oxygen-gas torches on lime hearths from the time of Deville and Debray in 1859 until about 1930, when induction melting began on a limited scale. As a result of improvements in furnaces, including converters and crucibles, induction melting of platinum increased in popularity and has now superseded torch melting except for some grades of scrap where the fluxing action of lime is advantageous. Jewelry manufacturers who produce their own precision castings use special melting techniques, as will be described in a subsequent article.

In primary fabrication, gold ingots (100 to 150 oz.) are cold rolled throughout, but ingots of platinum and palladium (100 to 500 oz.) are hot forged and hot rolled prior to cold working. Depending on the hardness of the platinum and palladium alloys, the hot working temperatures will extend from 1500 to 2300° F. Reducing atmospheres are used when possible for annealing gold alloys; otherwise the metal must be protected from oxidation by coating with boric acid. An oxidizing atmosphere is used for annealing platinum, but a neutral or inert atmosphere, such as nitrogen or steam, is preferred for palladium. Refiners generally carry fabrication as far as strip, wire and tube. Rolling mills for gold will seldom exceed 25 to 30 hp. with rolls up to 10×12 in. Typical hot rolling mills (20 to 30 hp.) for platinum and palladium have rolls 18 in. diameter by 15 in. wide for strip and 12 in. diameter by 30 in. wide for wire bars. Other equipment includes power presses with capacities up to 50 tons.

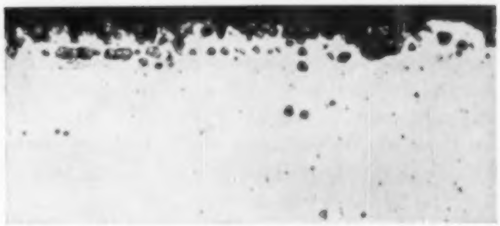
Wrought Parts and Findings

The term "findings", as generally used by manufacturers of jewelry, means parts of rings and other jewelry articles. Findings are generally made either by the jewelry manufacturer or by specialist firms. However, there is some overlapping of activities because a few refiners also

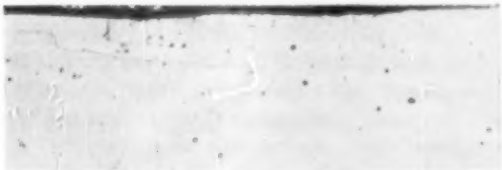
*Now retired, Mr. Atkinson was a metallurgist at International Nickel Research Laboratory. He resides in Westfield, N.J. This is the second in a series of four articles on metals for jewelry.



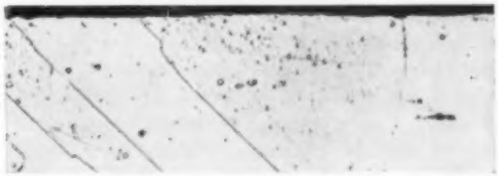
Oxygen-City Gas, Reducing. Ductility 1 to 4 bends



Oxy-Acetylene, Reducing. Ductility 20 to 21 bends



Oxygen-City Gas, Oxidizing. Ductility 19 to 20 bends



Oxy-Acetylene, Oxidizing. Ductility 24 bends

Fig. 1 – Effect of Heating 95.5% Palladium, 4.5% Ruthenium Strip Intermittently in Torch Flames for 7½ Min. at 2200° F. Surface of strip at top. (A-C electrolytic etch in 5% sodium cyanide, 500 ×)

sell jewelry parts and even rings ready for setting with stones. Conversely, most jewelry manufacturers will be equipped to do some rerolling of strip and redrawing of wire as a matter of convenience.

The principal metalworking processes involved in the manufacture of jewelry are blanking, coining, stamping and pressing. The techniques differ but little from those used for base metals. Coining, a method of cold forming or sizing by compression, is economical in material; furthermore it has the great advantage that coined articles have polished surfaces as they come from the machine, provided the dies have highly polished surfaces. These features explain the popularity of coining methods for the manufacture of jewelry. Coining equipment includes drop hammers, coin presses, screw presses (percussion) and hydraulic presses.

Intermediate annealing of the work hardened pieces is commonly done with air-gas torches unless the volume of work is enough to justify the use of an annealing furnace. The flame should be reducing for annealing gold, but for platinum and palladium the flame should be definitely oxidizing. Special care is necessary in the case of palladium; a short anneal (1 to 2 min.) at about 2200° F. with a hard flame is recommended, after which the metal should be quenched in water to avoid oxidation during cooling. Repeated use of an incorrect flame for annealing palladium can cause such troubles as blistering and "feathers" in thin strip and embrittlement in wire, so such materials should be annealed in a furnace, preferably with a neutral or inert atmosphere.

Rings, watch cases and many miscellaneous jewelry parts are made by coining. Seamless wrought rings are usually made from washer-shaped blanks in special coining machines. Other rings are made from plain or fancy strip which is bent around a mandrel and soldered. Short lengths of strip for rings and ring shanks can be made by coining and long lengths are made by cold rolling with special rolls.

Jewelry chains are made by specialist firms who use the same machinery for making both precious metal and base metal chains. Since one person can man up to 20 automatic chain-making machines, production is concentrated in a few factories. Some wires used for making chains have solder cores for greater convenience in soldering; some wires are even more complex – for example, gold-clad wire with a solder core.

Solders and Soldering

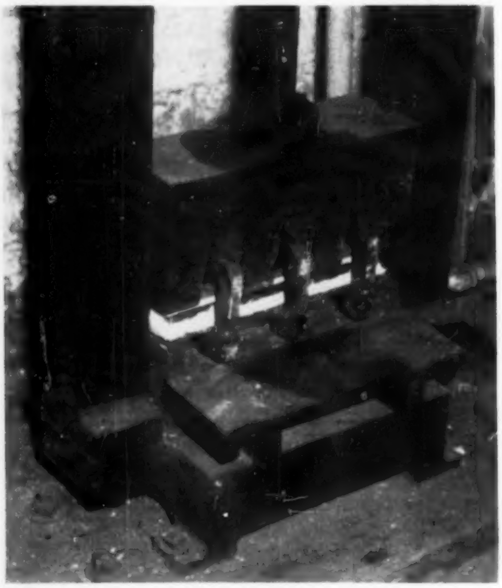
Many articles of jewelry are assembled by soldering together a number of components which might be either wrought or cast. However, in the assembly of gold-filled and rolled gold plate, soldering is avoided where possible and many joints are made by curling or rolling. Soldering is usually done with a torch. In the torch soldering of silver and gold it is necessary

to guard against oxidation by using a large reducing flame and a liberal amount of flux, usually boric acid. Because soldering temperatures are relatively low, a gas-air torch is used. E. M. Wise developed the following method of fluxing with boric acid, which is used in some factories and deserves to be better known. Air supply (or gas) to the torch is bubbled through methyl alcohol saturated with boric acid. Volatile methyl borate is formed, and enough is carried into the flame to form a thin layer of boric acid on the article being soldered.

A gas-oxygen torch with an oxidizing flame is used for soldering platinum and palladium. However, under certain conditions a small neutral or slightly oxidizing oxy-acetylene flame should be used for palladium. Platinum and palladium do not oxidize at soldering temperatures so a flux is not necessary, but can be used to help hold small pieces of solder in position until they melt.

A jewelry solder, in addition to the usual properties required in a solder or brazing alloy, should match the metal being soldered in color and in resistance to tarnishing. (Incidentally, it is no use telling a jeweler that his solders are really brazing alloys.) Requirements of stamping laws also have a bearing on the quality of jewelry solders, because the precious metal content (whether it be silver, gold, palladium or platinum) of the finished article must not fall below the prescribed amount. These varied requirements explain why jewelry solders contain relatively high contents of precious metals. Solders also have to be workable enough for conversion into thin strip or flattened wire (0.005 to 0.010 in. thick). The workability requirement indirectly assures adequate mechanical properties, which are not too critical. Great emphasis is placed on the making of joints with a minimum amount of solder; in some jewelry workshops the first job of an apprentice is to learn to cut solder accurately into very small pieces (even though solder can be purchased cut to size at little extra cost).

Fig. 2 – Heated Composite Bars Are Cooled Under Pressure to Complete Bonding. Bed and platen of the press are slotted to permit the application of pressure between the clamps. (Courtesy Krementz & Co.)



Complete specifications are available for silver solders (A.S.T.M. No. 3, 4, 5, 6) which are used for silver, but published information about other jewelry solders is usually limited to a descriptive name (such as "14K Yellow Gold Solder Hard") and the melting point. Each refiner probably has his own formulas for gold and platinum solders. Gold solders, some of which are from 2 to 4 karats below the karat of the article being soldered, formerly were made by melting karat gold and adding brass to lower its melting point. They probably are not greatly different at the present time, apart from the presence of 2 to 3% tin in some compositions. There are also karat gold solders which are "full karat". Solders used for platinum and palladium are basically gold-palladium alloys with the addition of platinum for the harder solders and silver for the softer ones; one of these solders is the binary alloy, 26% Pd and 74% Au, melting at about 2550° F., which is sometimes used as a temperature-limiting fuse.

When assembling hand-made palladium jewelry pieces of complicated design, involving numerous successive soldering operations, it is recommended that a very small neutral or slightly oxidizing oxy-acetylene flame be used instead of the usual gas-oxygen torch. Use of oxy-acetylene and a small flame were both considered quite revolutionary by old-style jewelry craftsmen, but the changes eliminated obscure cracking troubles which had been experienced when oxygen-gas flames were used for soldering palladium. The type of damage caused by an unsuitable flame is illustrated in Fig. 1 at top left. A reducing oxygen-city gas flame caused intergranular fissuring of the palladium to a considerable depth, resulting in almost complete loss of ductility; there was no significant loss of

Inco high-temperature research note:

Bunker "C" fuel oil

and its effects on heat resistant alloys

The use of Bunker "C" and other types of residual fuel oils for industrial heating poses a severe high temperature corrosion problem.

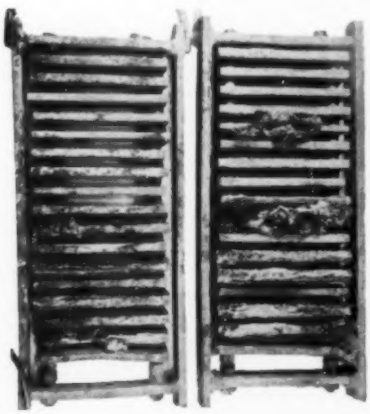
Combustion products from these fuels include a considerable amount of ash containing vanadium pentoxide, sodium and sulfur compounds, which have a low fusion temperature.

When this ash is liquid, it creates a fluxing action on the metals and high corrosion rates follow.

Since long field experience has shown all of the heat resistant alloy to be susceptible to this type of damage, an approach based on the addition of substances to the fuel oil to prevent the ash from becoming molten has been adopted.

Inco High Temperature Engineering Service conducts in-plant tests

Inco engineers—in cooperation with several Steam Power and Stationary Gas Turbine companies have conducted a series of in-plant tests in order to determine the behavior of certain high temperature alloys when exposed to Bunker "C" burned with or without additives.



Test racks after exposure

Each rack carried many specimens of different compositions, all precisely measured before installation. Corrosion rates are developed from these specimens by metallographic examination.

Corrosion results were obtained on both cast and wrought alloys as well as on some alloys with various coatings. The bar graph (below) shows the results of nine of the alloys tested. (Note for example, the performance of type 310 under the severe vanadium, sodium and sulfur environment.)

In general, data derived from this Inco High Temperature test points up the benefits of using additives when burning Bunker "C" fuel oil. It also provides a basis for material selection in terms of cost and length of service.

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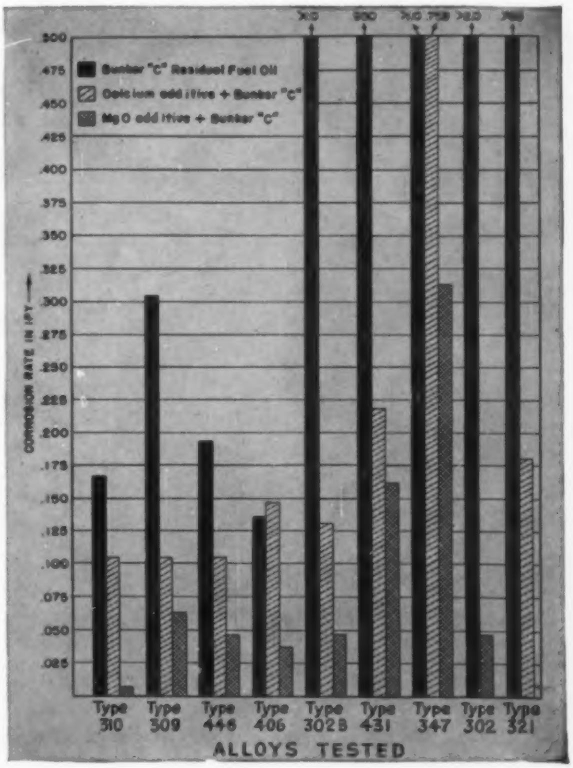
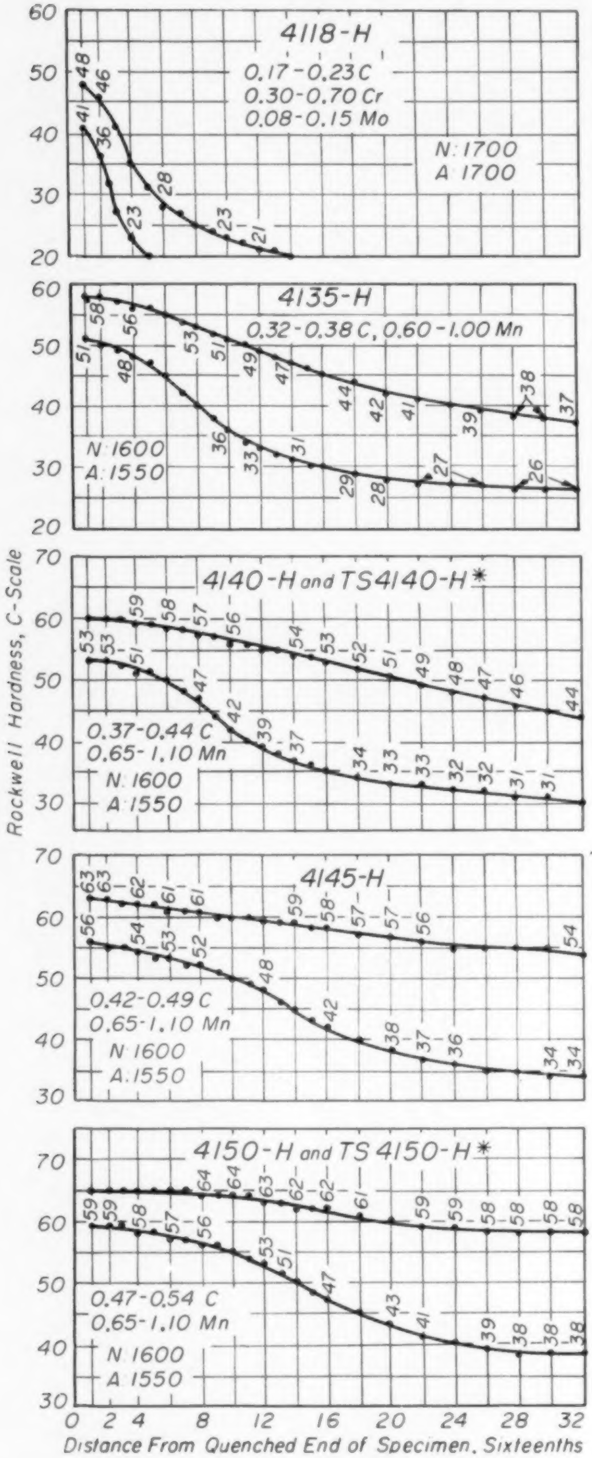
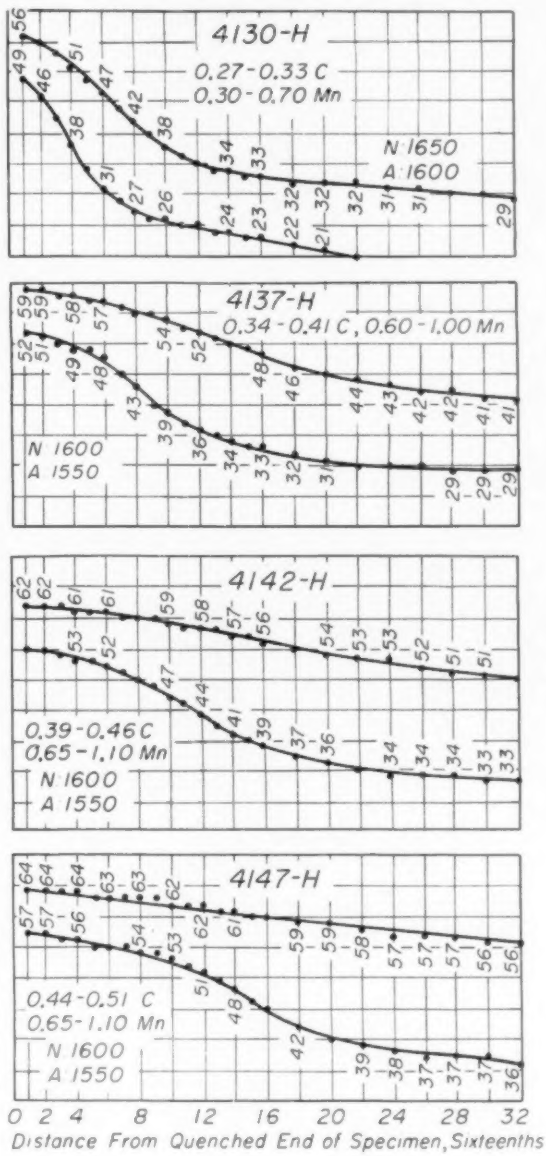


Hardenability Bands for Steels 4118-H to TS 4150-H

A.I.S.I. list of March, 1957

41xx-H Series has 0.20-0.35 Si, 0.75-1.20 Cr, and 0.15-0.25 Mo except as shown.





***Analyses of Tentative Standards**

	TS 4140-H	TS 4150-H
C	0.37-0.44	0.47-0.54
Mn	0.70-1.20	0.70-1.20
Si	0.20-0.35	0.20-0.35
Cr	0.85-1.30	0.85-1.30
Mo	0.08-0.15	0.08-0.15

N means normalizing temperature for forged or rolled material; A means austenitizing temperature (both as recommended by S.A.E.).

Hardness limits are specified in Rockwell C-scale units (no fractions) and can be scaled from the plotted points where not labeled at even sixteenths.

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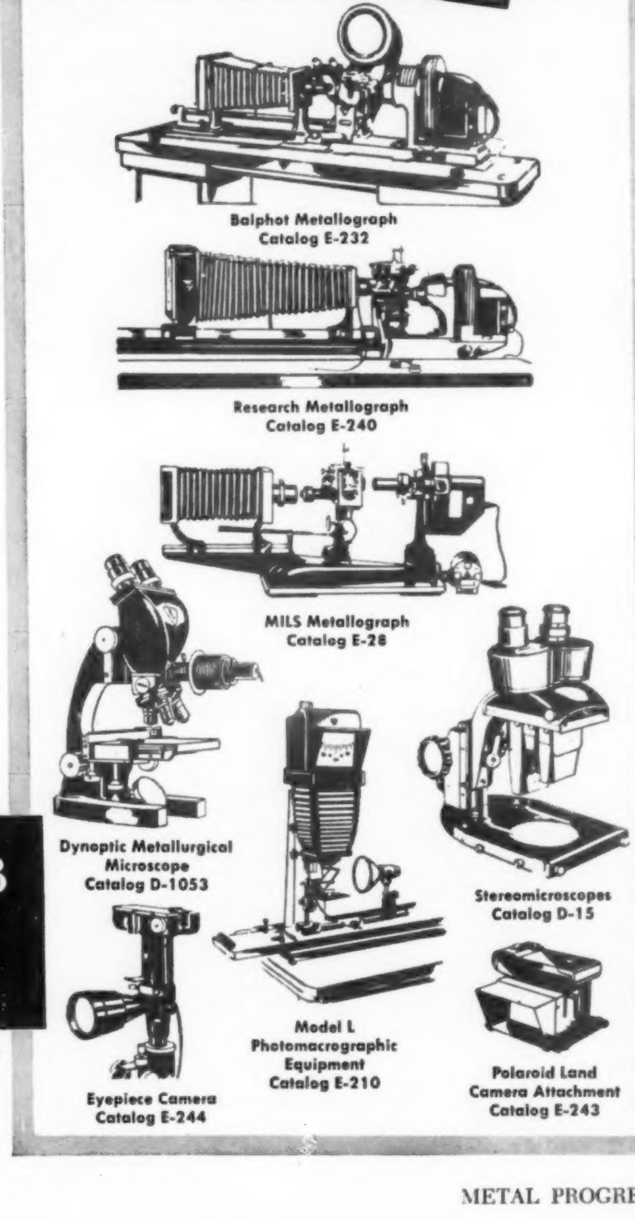

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ductility with any type of oxy-acetylene flame. It is true that a reducing oxy-acetylene flame causes superficial damage to palladium, but such a flame, being luminous, can be recognized and avoided. An oxygen-city gas flame sufficiently reducing to be harmful to palladium could be used without being known.

Gold Cladding

A complete range of gold-filled and rolled gold plate jewelry, including rings, is made for both men and women. Jewelry of this type is growing in importance because it meets a need for quality jewelry, intermediate in price between expensive jewelry and low-cost costume jewelry; it probably accounts for more than one-fifth of the total production of jewelry by value and an even higher proportion of the gold consumption, because only the cheaper stones will be used in gold-clad settings.

For the purpose of marking, gold-filled and rolled gold plate are included with other precious metal jewelry in the previously mentioned Federal Commercial Standards. For example, the mark "1/10 12 karat Gold Filled" means that the covering of 12-karat gold (50%) is one-tenth of the weight of the total metal. The mark "Gold Filled" is restricted to composite metal in which the proportion of karat gold is not less than 1/20. Composite metal containing lower proportions of karat gold may be marked "Rolled Gold Plate", provided the fraction and the karat are included in the marking. The "Trade Practice Rules for the Jewelry Industry" promulgated by the Federal Trade Commission also recognize the descriptions "Gold Overlay", "Gold Plate" and "Gold Plated" subject to the same conditions as "Gold Filled" and "Rolled Gold Plate".

Articles of gold filled and rolled gold plate jewelry are made from gold-clad stock by processes which are similar to those used for wrought karat gold. The manufacture of the gold-clad stock is concentrated in a small number of plants where it can be combined with the manufacture of similar stock for watch cases, chains, optical frames and trim for pens and pencils. Concentration of manufacture is due to the relatively large capital investment, plus the specialized personnel required to produce gold-clad stock.

Base metals for the manufacture of gold-clad stock are supplied in the form of so-called "plater bars", which are either cast or wrought. Brass, bronze, gilding metal (95% Cu, 5% Zn), steel, silver, nickel, nickel silver, Monel and Inconel have been used at various times for cladding with gold. Nickel and its alloys are preferred, when available, for applications requiring superior corrosion resistance. In the case of nickel, plater bars are made from 10,000-lb. heats of low-carbon nickel (0.02% max. carbon) which are cast into ingots, forged, hot rolled and cut to the desired length; a typical bar might have a 4 × 1-in. cross section after surfacing.

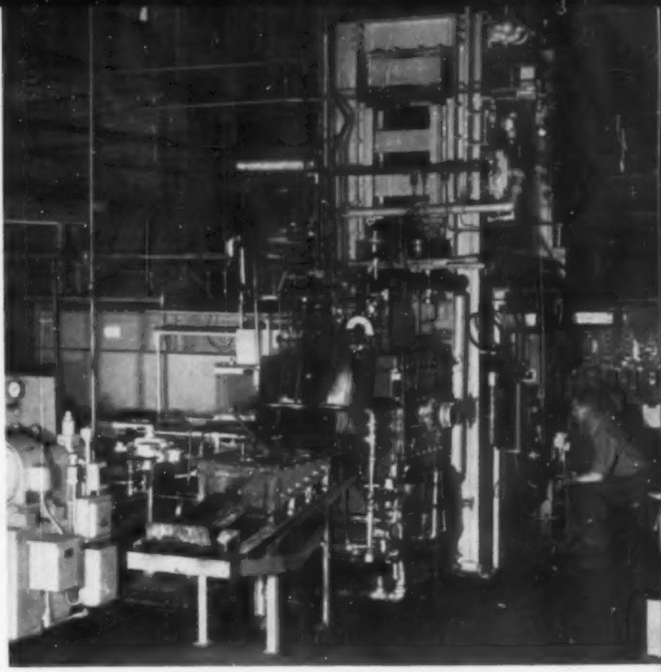
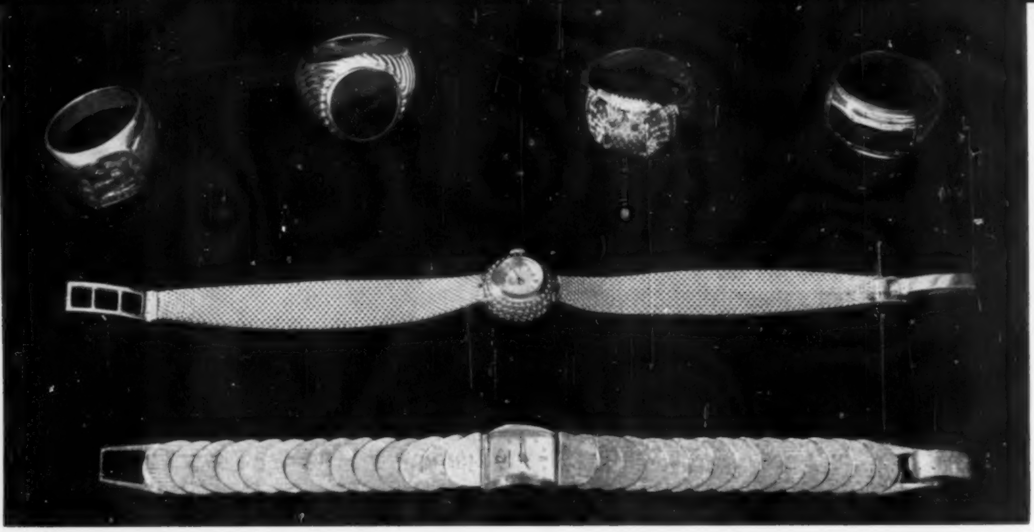


Fig. 3 – Pressure Bonding Furnace Used for Making Clad Metals. (Courtesy Metals & Controls Corp.)

The manufacture of gold-clad stock is the same in principle, regardless of the base metal. For example, with nickel as the foundation metal, a composite is assembled consisting of the annealed plater bar (which can be up to 24 in. long), a leaf of solder (about 0.002 in. thick) and a layer of gold. Special gold alloys, which have been developed for cladding, retain a close fine-grained structure when subjected to mechanical working without giving rise to the undesirable surface condition called "orange peel". The assembly is clamped between steel plates and heated to the melting point of the solder in a gas-fired furnace. Sulphur, which embrittles nickel, should not be present in the furnace atmosphere, in the paper and asbestos separators nor in the fluxes which might be used to protect the metal from oxidation. A furnace atmosphere which fluctuates between oxidizing and reducing is also harmful, since it can cause embrittlement of nickel even in the absence of sulphur. After the solder has melted the assembly is removed from the furnace and placed in a press where it is left to cool under pressure to complete the bonding. After bonding, the composite bar is



reduced to the desired thickness by cold rolling. For breakdown rolling a 50-hp. mill with 15 × 18-in. rolls may be used. Annealing can be done in either batch or conveyor-type furnaces; rolling lubricants, some of which contain sulphur, should be removed before annealing and, if the furnace does not have a controlled atmosphere, the metal should be coated with flux to protect it against oxidation. Annealing temperatures should be carefully controlled to promote recrystallization without melting the solder. In clad round bars there is a risk that molten solder will penetrate into the core, if it is under stress, resulting in solder embrittlement. Care and scrupulous cleanliness are necessary at all stages in the production of clad stock because extreme thinness of the gold layer in the final strip leaves no margin for refinishing to remove scratches or other mechanical damage.

A thin interliner of nickel is sometimes used in gold-clad brass stock for pen and pencil trim and other uses where a brass back would not be objectionable. Special care is necessary in annealing this type of composite metal to make sure that the nickel, which is out of sight, is adequately softened during each annealing.

Modern developments in the manufacture of rolled gold plate include "pressure" bonding furnaces (Fig. 3) and induction heating. In the former, the bonding pressure is applied inside the furnace, which is also supplied with a controlled atmosphere. Pressure furnaces can be used for bonding a wider range of metals, with or without the use of solder, than is possible with the older and simpler types of furnace. Induction heating has been suggested for bonding both flat stock and round bars but this technique is not now in widespread use.

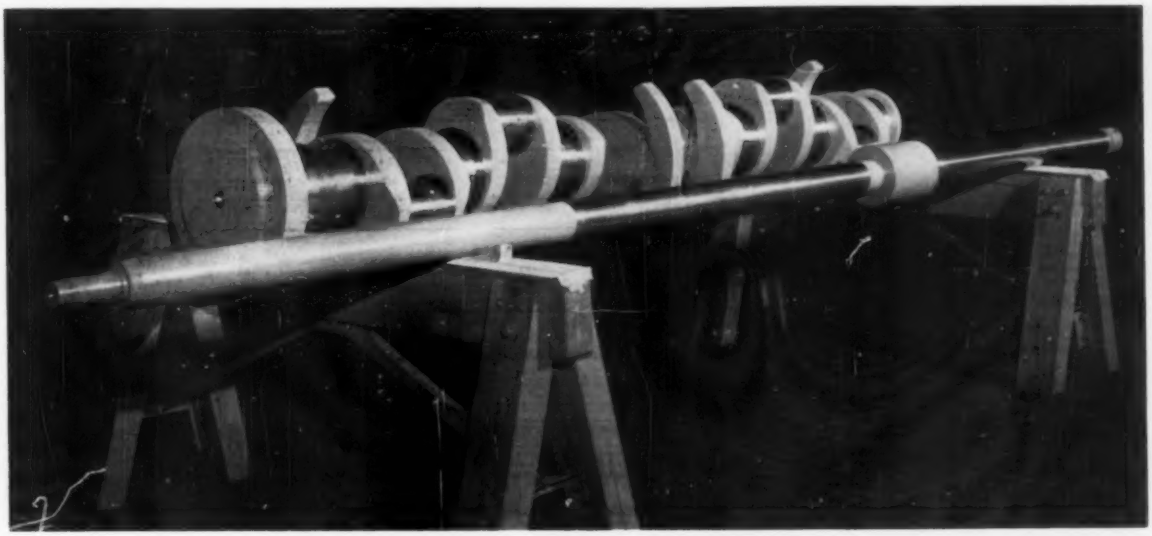
Platinum-clad and palladium-clad (the foundation metal is usually nickel) are made by methods similar to those used for making gold-clad; although these products are of minor importance in the jewelry field, platinum-clad has found at least one important industrial use.

Settings

There are several styles of jewelry setting, but the modern trend is toward "claw" and similar settings which allow the maximum access of light to the diamonds or other precious stones. Metal for the setting must be ductile and have a reasonably high yield point without being too hard. Jewelry platinum (95% Pt, 5% Ir; yield point 24,400 psi.) and jewelry palladium (95.5% Pd, 4.5% Ru; yield point 23,800 psi.) are popular for settings. The palladium alloy is often used for settings of white gold rings because the ordinary white golds are too hard.

Finishing includes polishing and plating. Polishing precious metals is a complicated art which may involve lapping, buffing and brushing with fine abrasive compounds, tripoli and rouge. Separate wheels dressed with "white rouge" (a polishing compound containing alumina and barium sulphate) are used for polishing platinum and palladium to avoid picking up particles of yellow gold or red rouge which would affect their color. Since palladium takes substantially longer to polish than gold, there is still need for improvement in the art. Soldered pieces are usually plated with a thin layer (less than 5 millionths of an inch) of either gold or rhodium, depending on the color, to hide slight differences in shade between the metal and the solders.

Rhodium, which has the highest reflectivity of the platinum metals, has become established as a plating finish for the white jewelry metals from silver to platinum. In particular, white gold, which is not truly white, is greatly enhanced in appearance by plating with rhodium.



Diesel Crankshaft and Compressor Piston Rod Ready for Nitriding. Light areas are tin-base paint for "stop-off"

Nitriding of Large Forgings

*By C. W. JOHNSON**

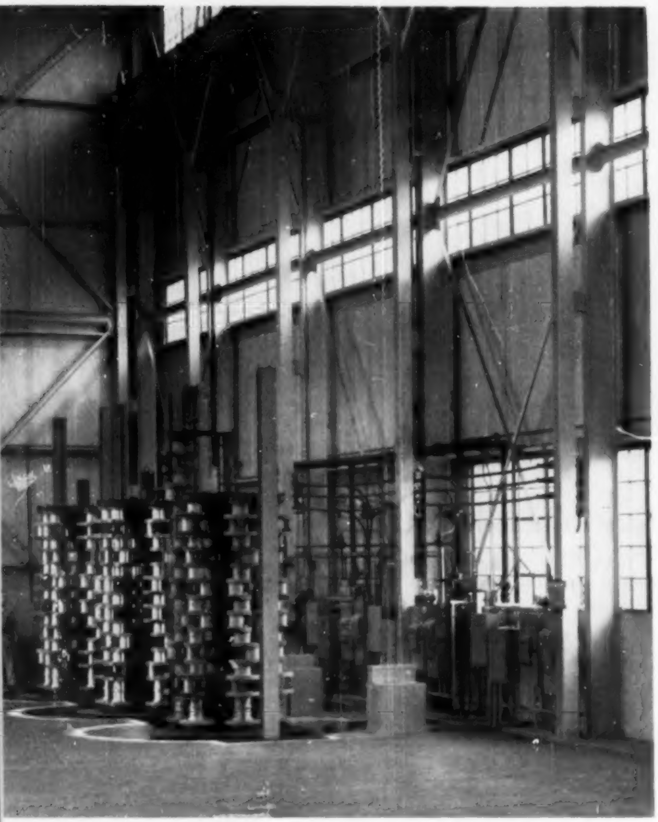
Large crankshafts for diesel engines, forged and completely machined, are nitrided by National Forge & Ordnance Co. As has been demonstrated for aircraft engine crankshafts, the nitrided surface (being in compression) notably increases fatigue strength and endurance, as well as wear. (J28k; AY, 4-1)

NITRIDE HARDENING, which has for many years been confined to production hardening of relatively small steel parts, is now being done at the National Forge & Ordnance Co. on a production basis on large forgings. A satisfactory method was needed for hardening bearing surfaces of large diesel crankshafts. This led to a study of methods and construction of equipment. Diesel locomotive crankshafts are now nitrided in large numbers.

The features of the nitriding process which make it a desirable form of surface hardening for crankshafts are attractive for other large steel products. Distortion is minimized since no liquid quench is needed, and the piece is subjected simultaneously to a prolonged stress-relieving treatment, thus minimizing residual manufacturing stresses.

During World War II, aircraft crankshafts were subjected to extensive fatigue tests. Thousands of them were nitride hardened with such good results that fatigue failures practically

*Chief Metallurgist, National Forge & Ordnance Co., Irvine, Pa.



Three Furnace Bases Stacked With Crankshafts 13 Ft. Long. Another furnace can take 16-ft. pieces

ceased. This, and other applications for nitriding, led us to experiment with the possibility of nitriding to improve and strengthen the diesel crankshafts which are produced in large quantity at our plant in Irvine, Pa. Actual sections of full-sized diesel crankshafts have been tested for fatigue strength, which we found to be increased by more than 30%, and the fatigue life at higher stresses was also greatly extended.

In addition to increasing fatigue life and strength, the case produced by nitriding is extremely beneficial in increasing wear resistance. Furthermore, the treatment can be applied to all or any selected portion of the part. Fillets adjacent to bearing surfaces and other surface discontinuities such as oil holes and keyways are easily hardened to the same degree as the journals. When an area is to be left unhardened, it can be blocked off effectively and economically.

Surface features which may produce stress concentrations (such as fillets, scratches or threads) seem to be less detrimental to nitrided materials than to carburized parts or those treated by other conventional hardening methods. Fatigue failures in nitrided materials start at the junction of case and core rather than at the extreme surface and are of rare occurrence except in severely overstressed materials. This tends to minimize the effect of minor surface discontinuities as stress concentration points and thus increases the endurance limit.

Nitriding of steel may be done by heating it in a protective atmosphere containing ammonia gas at approximately 1000° F. At this temperature the ammonia partially dissociates, releasing nascent nitrogen which combines with elements in the steel to form exceedingly hard nitrides which diffuse inward slowly. The hydrogen of the dissociated gas helps to provide a nonscaling atmosphere. At National Forge's plant a dissociator is used to break up substantially all of the ammonia into hydrogen and nitrogen before it is introduced into the furnace, thus giving better control of the surface "white layer" and depth of nitrided case. It also economizes on gas consumption.

Even though the "Nitralloy" grades are especially designed for nitriding (as well as a "standard nitriding steel" in the A.I.S.I. standards containing 0.40 C, 0.60 Mn, 1.60 Cr, 0.35 Mo and 1.15 Al) many other steels are very receptive. Diesel crankshafts manufactured from A.I.S.I. 4130 (1.0 Cr and 0.20 Mo) nitride readily and the same treatment develops core properties required for diesel service. 4330 and 4340 steels (1.75 Ni, 0.80 Cr, 0.25 Mo) are also receptive to nitriding. These low-alloy steels have the inherent strength and toughness required in the cores and avoid brittle cases sometimes found in Nitralloy.

Specifications for nitride hardened parts will vary for different applications. This variation is controlled principally through the grade of material to be used and whether it is forged or a casting. One proven specification for diesel application follows:

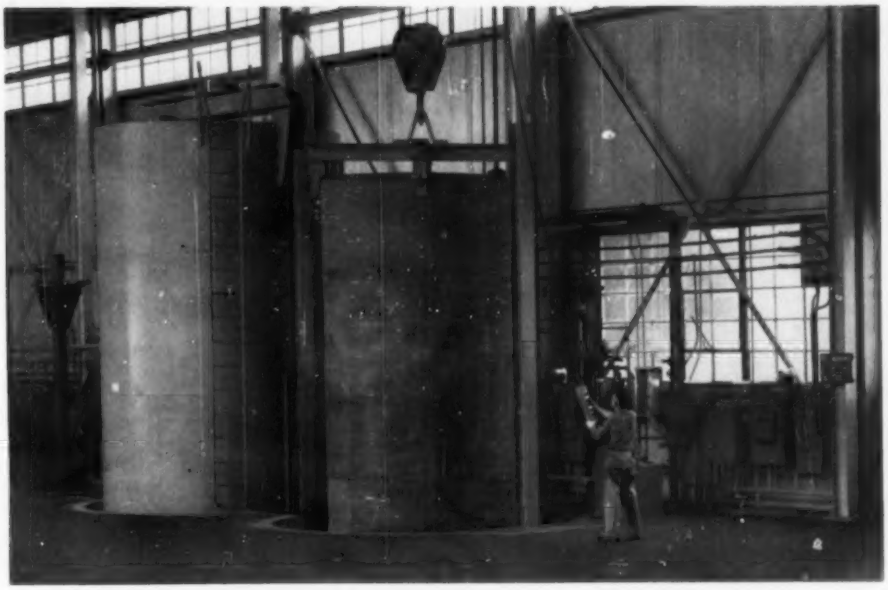
Steel: A.I.S.I. 4130.

Treatment: Air quench and temper to 80,000 psi. min. tensile strength, 45,000 psi. min. yield point, 20% min. elongation, and 45% min. reduction of area.

Case depth: 0.020 in. min.

Case hardness: At least 85 Rockwell 15-N on surface.

A typical treatment cycle consists of a prepurge(in which air is removed from the furnace bell), heating at 1000° F. in cracked ammonia,



Workman Is Lowering Gas Muffle Over Load; Alongside, the Furnace Shell (Electrically Heated) Is in Place; at Far Left Nothing but a Supporting Mast Appears of the Third Furnace Location

and post-purge. All operations combined require 120 furnace-hours. It is more economical than the time cycle would indicate, because of the large capacities of the National Forge & Ordnance Co.'s specially designed furnaces. All are equipped with high-velocity fans which effectively recirculate the furnace atmosphere, provide maximum uniformity of temperature and maximum contact between metal surface and nitrogen-rich gases. Recirculation also utilizes the ammonia most effectively and provides a uniform nitride layer on all exposed surfaces.

One reason for the undoubted increases in the endurance limit of nitrided shafting is that the nitrided case imparts high compressive stresses to the surface layer (also giving increased rigidity as well as wear resistance). Most fatigue failures start from high tension stresses at the very surface; the "built-in" compression of a nitrided layer thus reduces the magnitude of the tension stresses imposed by service loadings. The case depth will vary with the type of steel and the treating cycle. Dependent on these factors, cases may be produced which will vary from 0.010 to 0.050 in. in depth. In a normal case the maximum hardness will penetrate to a depth of approximately 0.015 in.; deeper there is a gradual tapering off of hardness down to the unhardened core.

Since nitride hardening is done in a controlled atmosphere and requires no quench, surfaces can be completely finished before the treatment. Nothing more than polishing or lapping needs to be done later. The process eliminates the possibility of quenching cracks and residual internal hardening stresses, both of which may be detrimental to the service life.

We measure the surface hardness with a superficial hardness testing machine using the Rockwell 15-N scale. Further and more complete examinations are made with a Tukon hardness testing machine, capable of micro-examination and hardness readings on individual grains.

At the time of writing no substantial amount of data is available regarding the relationship between stress and number of alternations to failure (S-N values) of the larger shafts and bars; generally speaking, as the diameter of the bar is increased the benefits of nitriding decrease, since depth of case remains fairly constant. Although the tests on straight bars of large diameters do not show quantitatively the improvement in fatigue resistance, there is no question but that the gain in strength is considerable.

There are many machine components now in service which are very expensive to maintain. A careful study might indicate the economy of replacement with nitride hardened parts.

Recrystallized Surfaces of Aluminum Extrusions

*By GUY V. BENNETT**

"Cold" work at surfaces of extruded bar may nucleate recrystallization of deep surface layers, producing a layer of metal of low strength and endurance. (N5, Q general; Al, 4-8)

EXTRUSION imparts varying degrees of work, both hot and cold, to the fabricated shape. Sometimes sufficient cold work on the outer layers of the section lowers the recrystallization temperature below the proper solution heat treatment temperature. Two examples of extruded sections showing this effect in varying degrees are shown in Fig. 1. Both photographs are of identical extruded sections of aluminum alloy 2014-T 6; note the great difference in the degree of recrystallization resulting from variation in extrusion practices. A lesser amount of cold work while extruding was imparted to the section shown at the left.

Many mechanical, physical, and fabrication properties of metals and alloys are affected by grain size. As an example, it is generally true that the tensile strength and yield decrease and the tensile elongation increases as the grain size increases.

Inasmuch as there is a trend in the aircraft industry toward the use of larger and larger extruded structural members – which usually simplifies the necessary machining – and since it has become apparent that many engineers do not realize that recrystallized surface grain is sometimes present in such sections, it would be well to point out some of the effects of large recrystallized grain.

Of the many aluminum extrusions now in use, the aluminum-copper alloys 2014 and 2024 are among the most prone to recrystallization. (2014 is 14 S containing 4.4% Cu, 0.8% Si, 0.8% Mn and 0.4% Mg, whereas 2024 is 24 S containing 4.5% Cu, 0.6% Mn, and 1.5% Mg.) The section selected for testing was a 2½-in. square of 2024-T 4. A photomacrograph of a wafer cut from the section is shown in Fig. 2, and the minimum depth of the recrystallized grain was about 0.07 in. Tensile and axial-load fatigue coupons were cut from the surface and T/4 locations as shown in red, and machined to a thickness of 0.065 ± 0.002 in.

Sixteen surface samples and 16 T/4 samples were tested in tension with these averages:

	SURFACE	T/4 LOCATION
Ultimate	57,200±1500 psi.	79,700±2500 psi.
Yield (0.2% offset)	43,000±1000	59,500±1100
Elongation in 2 in.	21.3±4.5%	11.8±2.0%
Hardness	E-101±1	E-101±1

The grain size of the T/4 specimens was appropriate to the size of the extrusion; all

*Materials and Processes Research Engineer, Douglas Aircraft Co., Inc., Tulsa Div., Tulsa, Okla.

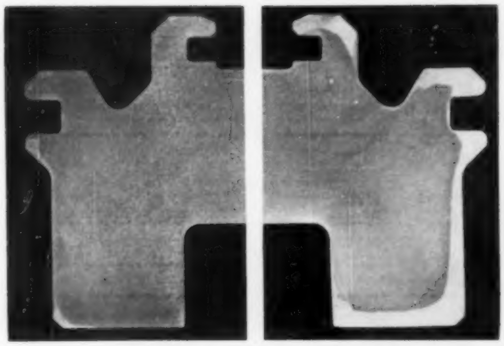


Fig. 1 — Extruded Half-Sections of Aluminum Alloy 2014-T 6, Etched in Hot NaOH. Recrystallized metal (light tone) is confined to corners and protruding lips in the left example; the other possesses a deep layer of coarse-grained metal

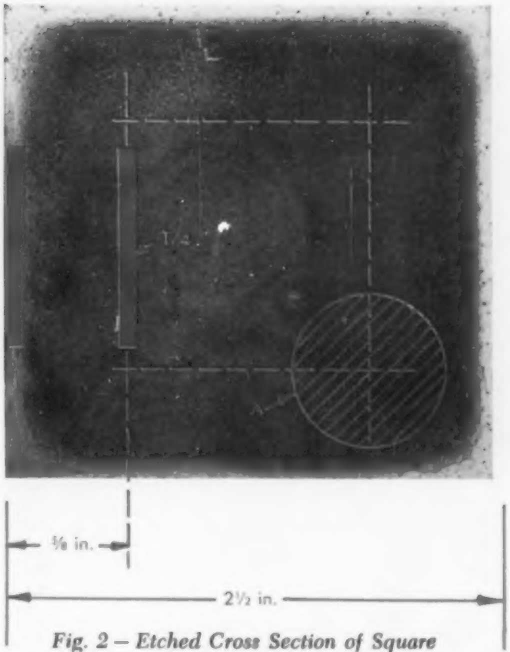


Fig. 2 — Etched Cross Section of Square Extrusion, Showing Location of Surface and T/4 Test Pieces in This Investigation as Well as Specified Position A of Tensile Test Piece for Acceptance

surface specimens were composed entirely of large grains. The tensile and yield of specimens cut from the outer layer were approximately 72% of the same values from the T/4 specimens. On the other hand, the elongation was nearly twice as large in the surface (recrystallized) material. There was no appreciable difference in hardness of the two locations, all values ranging from Rockwell E-100 to 102. Measurements were made on several different grains in each coarse-grained specimen without uncovering any difference.

Autographic stress-strain curves showed that the metal both at the surface and in the core elongated according to Hooke's law and had the same modulus of elasticity. A typical surface (coarse-grained) specimen departed from a linear relation about 4000 psi. below the 0.2% offset yield; in the finer-grained specimens from the T/4 location this departure was about 7000 psi. below the 0.2% offset yield.

Endurance is compared in the S-N diagrams of Fig. 3, which indicate inferior fatigue strength of the recrystallized grain below about 500,000 cycles. At somewhat smaller dynamic stress permitting longer life, this inferiority disappears — in fact, there is some indication in Fig. 3 that the coarse-grained material is slightly superior to fine-grained at life cycles greater than 1,000,000, but there are not enough plots in this range to confirm this behavior.

The marked difference in grain size at the

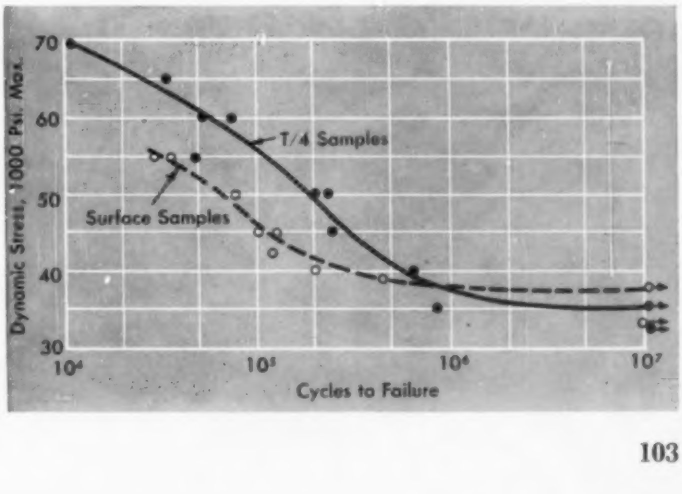


Fig. 3 — S-N Diagrams (R = + 0.2) Show That Fine-Grained Extrusion of Alloy 2024-T4 Has Considerably Better Endurance Under Heavy Loads

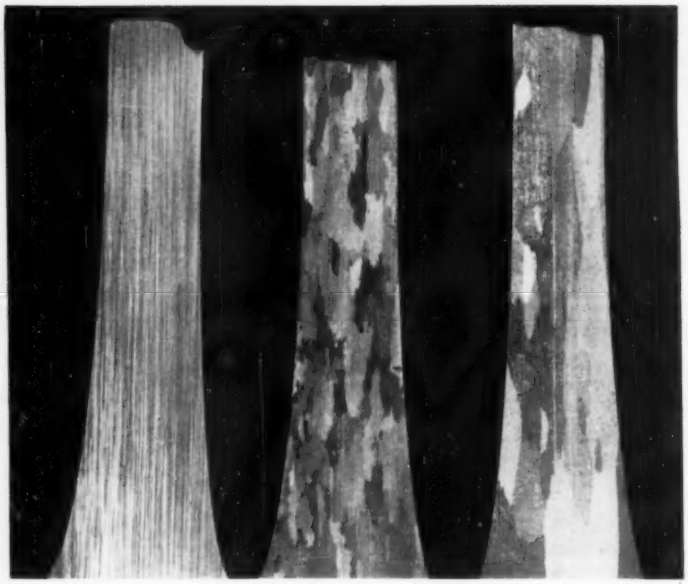


Fig. 4 — Surfaces of Etched Fatigue Specimens (Strips). Left is a fine-grained T/4 specimen; center represents the inside of a surface specimen; right is coarse-grained metal at the very outside of the extrusion

two locations in the bar can readily be seen in Fig. 4. The specimen at the left was from the T/4 location, those at the center and right are inner and outer surfaces of one machined from the recrystallized surface layer. The grain size of the surface specimens was very coarse at the surface of the extrusion, becoming smaller toward the unrecrystallized center. The surface shown in the center of Fig. 4 was close to the interface between as-extruded grain and recrystallized grain. Realizing that (*a*) the degree of cold work determines the recrystallization temperature, (*b*) the cold work is greatest at the surface and (*c*) any amount of cold work in excess of the amount to nucleate recrystallization at the solution heat treatment temperature will coarsen the grain, one would expect continually increasing grain size from the recrystallization interface outward toward the surface of the extrusion.

Discussion

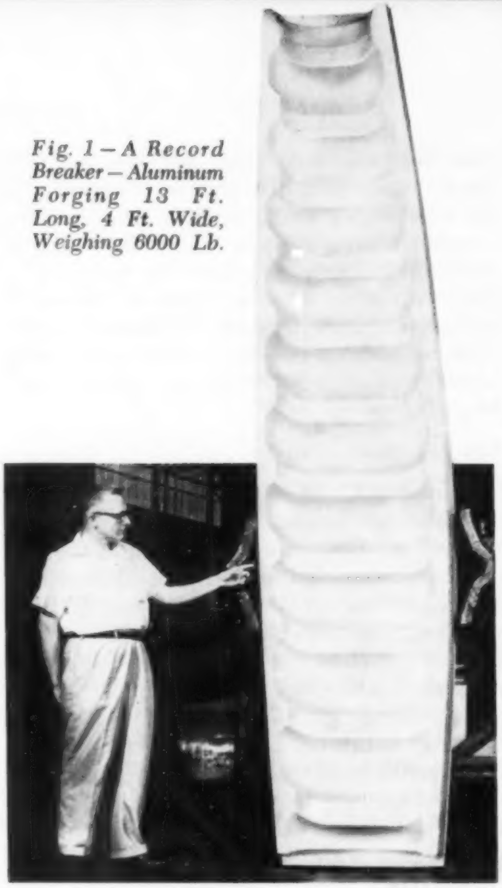
Although the data presented here were obtained with the 2024 aluminum alloy, the tensile properties, hardness, and fatigue behavior of other extruded aluminum alloys are doubtless also affected by recrystallized surface grain. The magnitude of the effect would not necessarily be the same as that reported here, as the "critical grain size" of another alloy may not be similar. However, these data indicate that a marked difference in properties between the core and surface can exist.

The bar used in this study met the tensile requirements of the procurement specification. This stipulates the location of the test bar. With the possible exception of sections less than ½ in. thick, the surface grain is seldom included in the tensile test specimen. The letter A on Fig. 2 represents one possible test-bar location, but it could be obtained from any position along the closed square dotted line shown in the sketch. No bar cut in this method would include any recrystallized metal.

An occasional part (generally a Tee, channel, or angle) is machined from an extruded bar, and one surface would normally correspond to a flat on the part cut therefrom. If the original bar had a recrystallized surface, it is entirely possible that a part of substandard properties will result. This can be avoided by using a larger section and machining off all the original surfaces.

Finally, the problem of prevention might be considered. Basically, coarse-grained surface metal can be avoided by controlling the degree of cold work during extrusion. The producers could not accomplish this without some concessions by the users. Occasions can and do arise where, due to the alloy and configuration being extruded, it is impossible to avoid some recrystallization at portions of the surface. By altering the section dimensions, or by changing the alloy to one that is less prone to recrystallization, this could be avoided in sections where their presence constitutes a design inequality.

Fig. 1 – A Record Breaker – Aluminum Forging 13 Ft. Long, 4 Ft. Wide, Weighing 6000 Lb.



Heavy Press Forgings for Aircraft

*By E. C. WRIGHT**

Hydraulic presses of 35,000 and 50,000-ton capacity make aluminum forgings of record size. However, the higher pressures produce the smaller forgings to much closer dimensional tolerances, thus reducing weight of forging one-half and final machining time to one-eighth. (F22, W22p, 1-2; Al)

JET ENGINES for aircraft propulsion have completely revised the design and construction of military aircraft. This transition is as revolutionary as that which occurred after World War I, when construction changed from spruce wood, wire, and doped canvas to the all-metal structure with radial engines. The jet engine brought with it a tremendous demand for increase in strength and rigidity in airframe structural sections. Wing loads greatly increased, wings were sharply swept back and thinned down to serve the new conditions of flight and sonic or supersonic speeds. No longer could thin skins be riveted on a built-up skeleton with its many mechanical joints; the wing skin had to serve both as a load-carrying member and as a lifting surface. These higher stresses required the fewest possible mechanical joints in built-up sections to avoid the greatly increased fatigue stresses (since the notch effect of joints in assembled sections was intensified). Attaching the new type of wing to the fuselage also became very difficult, requiring internal joining of large wing-supporting sections to similar sections forming the skeletons of the fuselage. About the only good way to do this was to use very large aluminum or magnesium alloy forgings.

Prior to World War II, most light alloy forgings were rather small in area and were produced on steam or air-operated drop hammers, in conventional dies. Operations and equipment were similar to those used for steel forgings. The parts produced were not only relatively small in over-all dimension, but had wide dimensional tolerances and generally were of such shape that they could be machined fairly readily to final dimensions. Die blocks did not exceed 6000 lb. in weight and were not much over a few

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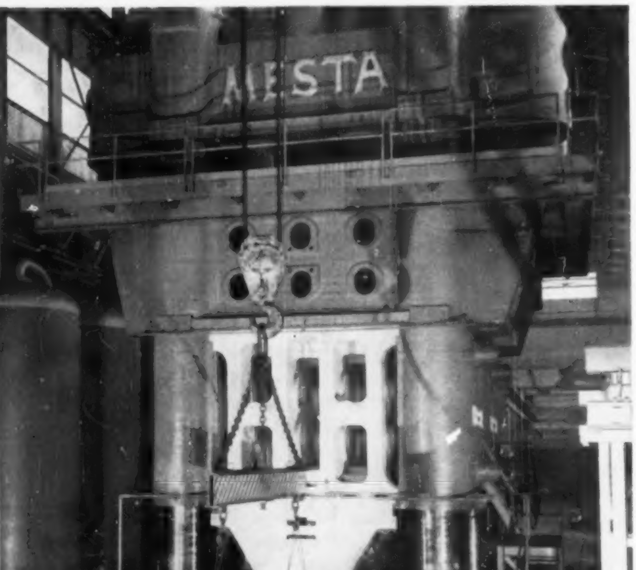
square feet in plan area. Drop hammers of 20,000 to 40,000-lb. capacity were adequate.

In contrast, some newly designed, heavy press forgings have reached the weights of the old die blocks (6000 lb.) and have sections as great as 13 × 4 ft. in plan. (See Fig. 1.) The required dies naturally have a very large working area, and a great thickness to withstand the enormous pressures necessary to flow the metal snugly into the die cavities. Die blocks weighing 20,000 to 30,000 lb. are now common; blocks weighing more than twice as much are probable. Such die masses cannot be operated in a drop hammer; only hydraulic presses can be used. Presses have the further advantages of maintaining high die temperatures, more uniform metal flow under sustained loading, and means of ejecting forgings from the dies by knock-outs.

None of these objectives can be reached when forging in drop hammers. Moreover, much higher dimensional accuracy may be attained in hydraulic presses; dies have much better alignment and decreased spring-back.

The pressure required ranges from 10 to 20 tons per sq.in. for "conventional" forgings of normal fillet radius and web thickness, and up to 30 to 40 tons per sq.in. for forgings with very

Fig. 2 – The 50,000-Ton Press at Alcoa's Cleveland Plant, Built by Mesta Machine Co. It extends as far below the floor as above, overall height equaling a 12-story building



small fillet and corner radii, thin webs and ribs, and closer dimensional tolerances. Theoretically, the huge forging shown in Fig. 1 would require pressures starting at about 100,000 and ending at about 180,000 tons (based on unit pressure) to forge on one set of dies. Since no presses of such capacities are available, this massive forging must be made in several pressing stages using several sets of dies with several reheating and forging steps.

The Mammoth Machines

Aluminum Co. of America had operated 1500 and 3000-ton forging presses since 1940 and the staff was familiar with the many advantages of presses over drop hammers. After World War II a 15,000-ton Schloemann press was brought over from Germany and installed in Alcoa's forge plant in Cleveland. It was soon discovered that much better forgings with respect to dimensional accuracy and mechanical properties could be made on this heavier press. As the demand for larger forgings arose in the aircraft industry, the need for even larger presses became apparent, so a study was undertaken to determine just how large a press could be built with existing engineering knowledge, what it would cost, and whether it would be economically feasible. It turned out that such an undertaking was too costly to be financed by private industry.

Consequently the U.S. Air Force decided to build two 35,000-ton and two 50,000-ton presses. One each was installed at the Alcoa plant in Cleveland and at the Wyman-Gordon forge plant at North Grafton, Mass., near Worcester. These new plants are the property of the Air Force and are leased to the operating companies. The 35,000-ton press at Cleveland was built by United Engineering & Foundry Co. and the 50,000-ton unit by Mesta Machine Co. Both of the large presses at Wyman-Gordon were built by the Loewy-Hydropress Division of Baldwin-Lima-Hamilton Co.

The two presses at Cleveland were "blown-up" traditional designs. Huge steel castings carry the platens and dies, and move up and down on alloy steel columns. Weight of metal in these presses comes to 6000 to 7000 tons. They rise 50 to 60 ft. above floor level and extend an equal depth below floor level to reach the foundations, the over-all height of the 50,000-ton press being 128 ft. – the height of a 12-story building! All the castings and forgings in this press were made in Mesta's own shops, where especially large machine tools were installed to finish these large

sections to precision tolerances. The 50,000-ton press is shown in Fig. 2.

The large Loewy Hydropress equipment (Fig. 3) was built on a novel design. Its total weight is 10,750 tons. It is called a "pulldown" press, since large hydraulic cylinders located below the floor level pull down the entire upper structure, whose weight thus increases the forging pressure. Dies are mounted on both upper and lower cross-head beams which weigh 150 and 120 tons respectively. These beams move vertically on square columns about 24 in. square, each consisting of three heavy slabs of steel 110 ft. long and weighing 100 tons. Six beams comprise the upper cross head and six the lower, similar in over-all size and shape but differing in web thickness; the upper beams have 12-in. webs and the lower 10-in. These main members were fabricated by welding, each beam requiring 2½ tons of weld metal! Welding was by submerged arc using high-manganese welding rods 3/16 in. diameter. The heavy sections were preheated above 300° F. Weld deposits about 2 in. thick were made on one side and then the whole beam was turned over to lay an equal deposit on the other. Thus welding alternated from side to side until the full 12 in. of seam was finished. The big beam was stress-relieved after each pass.

Design and Forging Problems

Many complex problems confront the producer of large precision forgings:

1. Press deflections must be maintained at a minimum.

2. Die alignment or mismatch must be carefully regulated.

3. Die temperature closely controlled.

4. Uniform temperature maintained in the forging stock.

5. High contraction of the alloys after forging compensated for.

6. Allow for die wear (and polishing of dies) which affects the dimensional tolerances.

7. Arrange proper knock-outs for ejecting the forging.

8. Control dwell time of pressure.

9. Allow for warpage or distortion during heat treatment of intricate and unsymmetrical shapes.

10. Minimize draft angles on webs and flanges and corner radii of fillets.

11. Make toolsteel inserts for high-precision forgings.

12. Lubricate dies.

One glance at the presses convinces the observer that most rigid assemblies are necessary

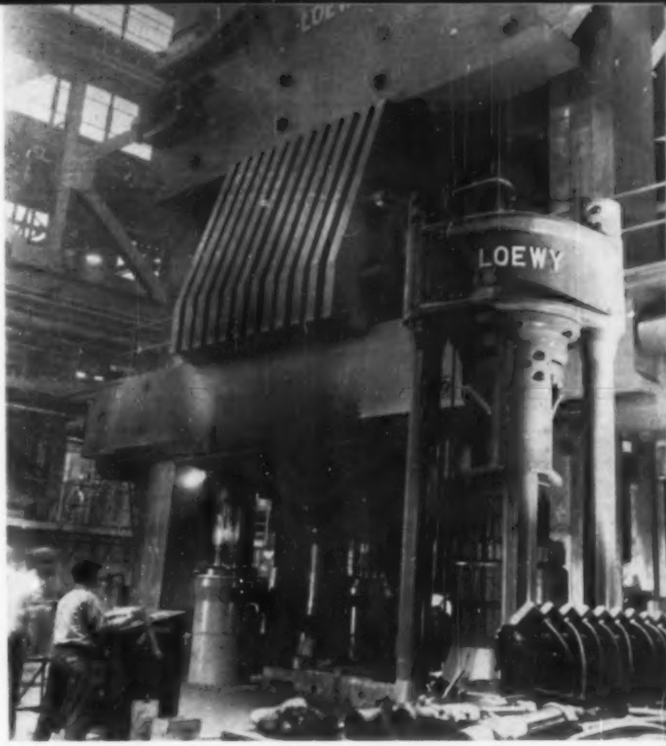


Fig. 3 – The 50,000-Ton Press at Wyman-Gordon's Grafton Plant, Built by Loewy-Hydropress. Actuating cylinders are below floor; of the 10,750-ton weight, 7500 tons move up and down

for aligning the dies and holders on the upper and lower platens. The general arrangement for distributing loads is shown in elevation in Fig. 4. The dies are held horizontally by the wedges and U-shaped keys and are aligned vertically by large pins extending through accurately bored holes in the hard plates and die blocks. The latter are made of alloy steel, hardened to about Brinell 400 (about the maximum for ready machining of the desired cavities).

A large inventory of die blocks and finished dies costing millions of dollars is maintained at these forge plants. The continual changes in aircraft design introduce new forgings for every new model, and dies must be made up for each newly designed part. A curious feature of this industry is that these costly dies are rarely worn out before some model change occurs. As a result the die cost alone for some of the larger forgings may be over $1000 per forging.

Sinking is a delicate and time-consuming operation; it becomes more difficult as forging tolerances are tightened. Die blocks are rough planed by the steel producer and then must be machined to a very smooth finish at the forge plant. All the dies, hard plates, die guide holders, and platens must be "plate-glass flat" to distribute evenly the high pressures. This smooth-

ing operation is called "shanking." Some idea of the machine tools and cranes required may be had from the fact that some of the blocks weigh 50 tons each.

While the shanking operation proceeds, models of the die cavity are made and templets cut showing cavity contours. Working from detailed drawings, highly skilled workers make an accurate replica of the forging of wood and plaster. Many factors that affect dimensional accuracy of the finished forgings must be considered. Plaster is then poured around the model to produce a negative which serves as a guide in the actual die sinking (Fig. 5).

Plaster model and flat die block are then placed in special die sinking machines. Here moving metal fingers trace every contour of the plaster model and duplicate automatically the same contours in the die block. Meanwhile the die sinker uses the templets as a constant check on the machine's accuracy. After sinking, the die surface is smoothed and polished to the desired finish and dimensional accuracy – largely a hand tool operation. At the same time accurate guide and ejector pins are made for holding the dies and hard plates in alignment.

Preparation of one set of large precision die blocks may require from 3 to 12 months' work. Many complicated forgings require more than one set of dies to gather the metal properly and flow it into thin webs or intricate cavities.

For these large forgings two types of dies are in use, depending upon the thinness of webs and closeness of tolerance specified. To decide this involved matter considerable discussion arises between the aircraft part designer and the forging producer. An improperly designed forging may require extremely high pressure to force metal into thin sections, pressures as high as 40 tons per sq.in. Sometimes a battle develops between the aircraft engineer, who wants accurate weight and least amount of stock to remove in awkward machining operations, and the forging manufacturer, who desires to reduce die cost and avoid excessive unit pressures at critical sections. Small fillet radii are especially trouble-

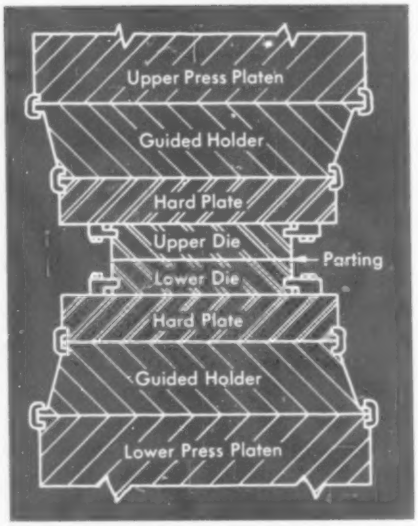


Fig. 4 – Cross Section of Die and Holder Arrangement for Heavy Press. Load on the die area is distributed, and pyramided to the much larger platen area

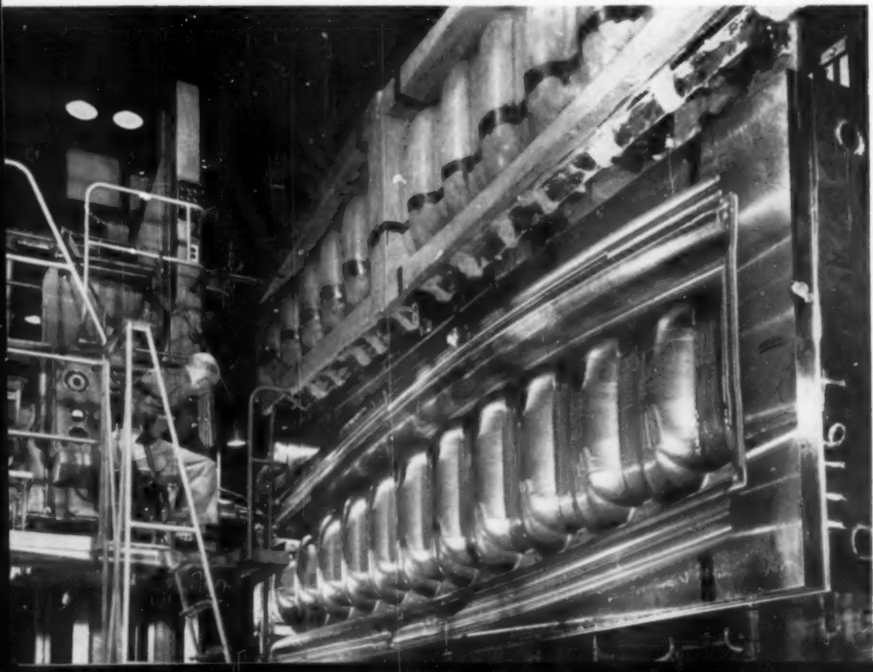


Fig. 5 – Oversize Alcoa Die Sinking Machine Making One of the 30-Ton Dies for the Forging Shown in Fig. 1. This required about 1500 man-hours. Courtesy of Aluminum Co. of America

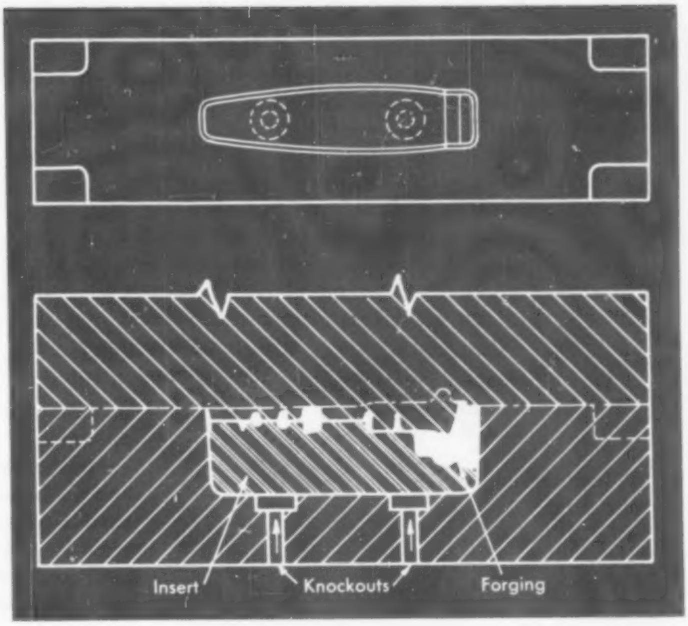


Fig. 6—Low Dimensional Tolerances and Minimum Draft Require Toolsteel Inserts, Which May at Times Be Used as a Knockout Device

some. The forger must also decide whether the part will require one or several sets of dies, always with the object of reducing unit pressures and resistance of the metal to flow.

Normal dies for "conventional" forgings are sunk to a tolerance of ±0.005 to 0.010 in. with draft angles on vertical ribs of 5° or more. When "no-draft" forgings are demanded with rib thicknesses under 0.150 in., tolerances of ±0.010 in., and draft angles of 3° or less, dies must be machined to an accuracy of ±0.001 in. to provide allowances for polishing the dies between runs. Such precision dies can only be made with specially fitted and hardened toolsteel inserts as shown in Fig. 6. The abutting surfaces of these inserts and yokes must be held to very close tolerances. These inserts may also be used as knockout devices.

One of the most critical features of the forging operation is the accurate control of the temperature of both forging stock and dies. Dies are heated for several hours (over night) to obtain an even temperature of about 800° F. and then are kept warm in the press by a series of gas burners surrounding them. This avoids chilling the stock as it is being forced to flow into thin sections. The time at which the pressure is maintained (dwell time) is also crucial and requires best judgment and experience for any given situation. The ingots or large forging billets are also soaked for many hours at forging temperature. The hot dies are lubricated with a spray of emulsified graphite; the hot dies ignite the oil carrier leaving a film of soot and graphite on the surface.

Metal for Forging

At Alcoa's plant in Cleveland the ingots for forging are cast in a special ingot area. Ingots weighing 8000 lb. may be cast. (Forging ingots of aluminum alloys 32 in. in diameter are being successfully cast by the Kaiser Aluminum & Chemical Corp. – see *Metal Progress*, November 1957, p. 70.) All ingots are scalped and machined to remove surface flaws, and then closely inspected with ultrasonics to detect internal flaws. Before forging, ingots are preworked to develop a wrought structure by extrusion, rolling or pressing depending on the shape desired for the forging stock. They are then soaked or homogenized for several hours at 650 to 850° F., depending on composition.

The final die forging is produced by a series of blocking and finishing operations. Blocking dies promote metal movement in preferred directions and produce required grain flow. One of the first forgings produced from a die is surveyed for conformity to mechanical property requirements and grain flow. Mechanical properties are determined at several locations and grain flow can be checked by visual inspection of machined and etched cross sections. Once established, the procedure becomes standard and no changes are made unless another mechanical property survey is made.

Finished forgings are solution heat treated and aged. Time at temperature varies with section thickness, ranging from 4 to 20 hr. Furnaces are electrically heated, and temperatures are 830° F. for 7079 alloy, 880° F. for 7075 and 940° F. for 2014. Quenching water is at 140 to 160° F. for 7075 and 2014, and at room temperature for 7079 alloy. Precipitation heat treatments are 8 to 12 hr. at 340° F. for 2014, 24 to 28 hr. at 250° F. for 7075, and 48 hr. at 240° F. for

7079. The latter alloy requires a five-day room-temperature aging between solution heat treatment and artificial aging.

Mechanical properties are typified by the following minimum values given in Federal Specification QQ-A-367d, Amendment 1:

Alloy	Tensile Strength	Yield Strength	Elongation*
	Parallel With Grain Flow		
2014	65,000	55,000	7%
7075	75,000	65,000	7
7079	74,000	64,000	7
	Transverse to Grain Flow		
2014	62,000	52,000	3
7075	71,000	62,000	3
7079	72,000	61,000	4

At least ten aluminum alloys and three magnesium alloys are now being forged on heavy presses for the aircraft industry. Some titanium alloys have also been tried but work on this new metal is still in the experimental stage. The magnesium alloys, with their hexagonal lattice structure, are more difficult to work than the high-temperature aluminum alloys. It is generally recognized that the various aluminum alloys are four to nine times as forgeable as magnesium alloys. Naturally the higher-strength alloys generally have greater resistance to flow in the press, and forgeability decreases as tensile strength increases. Thus the 80,000-tensile strength alloys such as 7075, 7076 and 7079 have about half the forgeability as the most easily worked alloy, 6151, with tensile strength below 50,000 psi. Alloy 2014 is still the most widely used and is recommended for most structural applications. Lately there has been a trend toward greater use of 7076 and 7079 because of their higher strength.

Forging Applications

As a result of this heavy press program many aircraft sections that were formerly made of sheet, plate, structural shapes, extrusions and other components may now be made as a one-piece forging. Many machining, welding, cutting, and riveting operations are avoided. This balances to a certain extent the very high cost of the large precision forgings. It is difficult to determine any average costs since there is great variation in size, complexity of design, quantities ordered, and particularly in the cost of die-making. In a sense the forger only supplies the metal and the finished forging since the dies are the property of the purchaser.

*Per cent in four diameters.

The vital engineering feature is that the aircraft builder has a much superior section, free of the many notches which are inherent in a fabricated assembly, with high and uniform properties throughout the cross section.

Some of the more important parts being produced on the heavy presses are (*a*) wing-beam fuselage carry-through fittings; (*b*) landing gear bulkheads; (*c*) tapered wing beams and spars (structural beams running the span of the wing); (*d*) reinforced skin panels which form the wing surface with structural stiffeners forged as part of the skin. The latter approaches the concept of finished aircraft sections squeezed out in one operation.

Most military planes are today experimental and no large numbers are required except those needed to supply the existing forces in the strategic and fighter command. If conditions such as existed during World War II ever again arose, production quotas of 10,000 planes per month might be necessary. The demand for heavy forgings would then be enormous and actual production costs might be much lower than exist today. A steadier and even larger market can be predicted from the natural growth of commercial aviation. Passenger traffic is expected to double by 1962 or 1963. Air freight, express and mail are increasing at a rapid rate. *Financial Times* of London forecast that about 6000 turboprop and jet transports will be built in the next 15 years. All this will give manufacturers of large forgings the necessary information so they can successfully expand their market into other branches of industry where dead weight should be eliminated. While present production figures are unavailable, upwards of 5000 tons of these forgings may have been made since 1954.

An example of the benefit gained when forgings are made on the heaviest presses (50,000 tons) is given by Burr Wilcox, chief of the manufacturing section, Air Material Command. A longeron support beam made on the 18,000-ton press required a round bar 10 in. O.D. by 60 in. long, weighing 53 lb. The eventual very irregular shape was 51 in. long, 6 in. wide on one end and 23 on the other. The web was ½ in. thick. Forging weight was 40.8 lb. and finished machined weight was 16.9 lb. requiring 43 hr. per forging. Wilcox estimates that this same part could be made on the 50,000-ton press with a forging weighing only 19 lb. and requiring only 5 hr. for finish machining.

Annealing of Steel Sheet

*Reported by G. W. FORM and E. B. EVANS**

While batch annealing takes hours, the product is softer and more desirable for deep drawing than that from the rapid continuous annealing. "Snakes" (a ripply surface) are suspected to be subsurface oxides, and they form even when the standard D-X atmosphere is maintained during annealing. Directional orientation of microstructure and strain aging characteristics are still matters which require correction in tonnage mill products. (J23; CN, 4-3)

MORE THAN 170 specialists from 14 states and 12 different nations gathered at Case in Cleveland late in October to discuss the annealing of low-carbon steel. The symposium was a cooperative effort of Lee Wilson Engineering Co., Inc. and Case Institute of Technology, with A. R. Troiano, head of the department of metallurgy, as general chairman.

The sessions considered primarily the process annealing cycle (heating below Ac_1 and cooling relatively slowly) of flat, cold rolled low-carbon steel containing 0.15% or less of carbon. Over 40,000,000 tons of this were made in the United States in 1956 (35% of the entire ingot production). Obviously, annealing is an important manufacturing operation. Eleven papers, one each from Wales, Canada, Germany and Russia, and seven from the United States, were presented at four sessions. Ten concurrent round-table gatherings considering performance criteria at a fifth session. The proceedings are scheduled to be published, and this brief account can hit only a few of the high spots.

Although a number of matters of vital interest to the producer as well as the user of low-carbon steel sheet were discussed, the main emphasis centered about three topics: batch versus continuous annealing, prepared furnace atmospheres, and quality of finished product.

Batch Versus Continuous Annealing

Howard E. Miller, assistant chief metallurgist of Republic Steel Corp., Cleveland, emphasized that fully strain-relieved material is the minimum requirement of the annealing operation — at least as far as cold rolled low-carbon steel is concerned. This is accomplished either by slow annealing cycles requiring hours (batch annealing) or by fast annealing cycles requiring but a few minutes (continuous annealing). Most commercial annealing treatments are conducted at 1250 to 1325° F. for 3 to 30 hr. in single or multiple-stack batch furnaces, or for about 1 min. in continuous annealing furnaces.

At first glance, the time factor would weigh heavily in favor of continuous annealing as far as economics are concerned. In fact the trend in recent years has been to continuous annealing lines at speeds ranging upward from 300 to as much as 2000 ft. per min. But it was pointed out in many lively discussions that some plant experience in the United States and Great Britain has shown that the economies are more apparent than real. For example, Lyle F. Gulley, vice-president in charge of operations for Granite City Steel Co. (Ill.) reported that batch annealing costs are sharply reduced by increasing the coil diameter to 72 in.

One real advantage of batch annealing noted by numerous conferees is that the product is slightly softer than continuously annealed material. Thus the batch annealed product is more desirable for deep drawing. On the other hand the stiffer continuously annealed product is of advantage in the production of such items as tin cans.

Harry H. Ascough, mills superintendent for the Steel Co. of Wales (Port Talbot), reported that British practice is, and will continue to be

*Assistant professors in the deparment of metallurgical engineering, Case Institute of Technology, Cleveland.

for some time, based on American experience in batch annealing. An interesting possibility is that Britain, short on natural fuels, will resort to nuclear reactors to heat the convector gas in annealing furnaces. (The atomic power reactors now in operation and under construction in England are gas cooled and the coolant emerges at a temperature too low to fuel a steam-electric plant operating at high thermal efficiency, but amply hot enough for many process industries.)

A comprehensive paper on continuous annealing was presented by Georg Niebch of Georg Niebch und Soehne, Germany. It emphasized that conventional recrystallization diagrams, representing equilibrium conditions, do not take into consideration the time effect, and therefore are not a very good guide for choosing a suitable short-time annealing treatment. Mechanical property tests, X-ray analyses, and microstructural changes plotted against the annealing time at various temperatures and after various cold reductions, revealed that hardness is a simple and reliable means for following the progress of recrystallization. He finds that the lowest hardness (and therefore the best properties) are obtained by annealing at 1290° F. Two minutes are required for complete softness and uniform grain structure at 1290° F., and the properties are relatively independent of longer times (or slower strip speeds) and the amount of cold reduction.

Prepared Furnace Atmospheres

A paper by George J. Campbell, assistant fuel engineer, Bethlehem Steel Co. at Sparrows Point, Md., on the use of prepared protective atmospheres in the annealing operation excited much discussion in the auditorium, in the corridors, and in round-table meetings. (The nature of these furnace atmospheres is treated rather comprehensively in a series of articles in *Metal Progress* in February, March and April 1957.)

Annealing of sheet steel is almost always done in one of two types of furnace atmosphere: (*a*) the so-called D-X or exothermic type (a satisfactory composition being 12% H_2, 9% CO, 5% CO_2, 12% H_2O, and balance N_2 formed by partial combustion of about 6 parts of air to 1 part of natural gas) and (*b*) dry hydrogen-nitrogen (4% H_2, 96% N_2). While the latter is the best atmosphere it is more expensive and is usually reserved for products where surface quality is paramount, as for plated ware.

The D-X type atmosphere is the work-horse of the annealing department but the chemical composition of the gas must be controlled within rather narrow limits to avoid surface defects. Lean mixtures (high CO_2 and H_2O) lead to oxidation; rich mixtures (high CO or small amounts of methane) lead to carbon deposits.

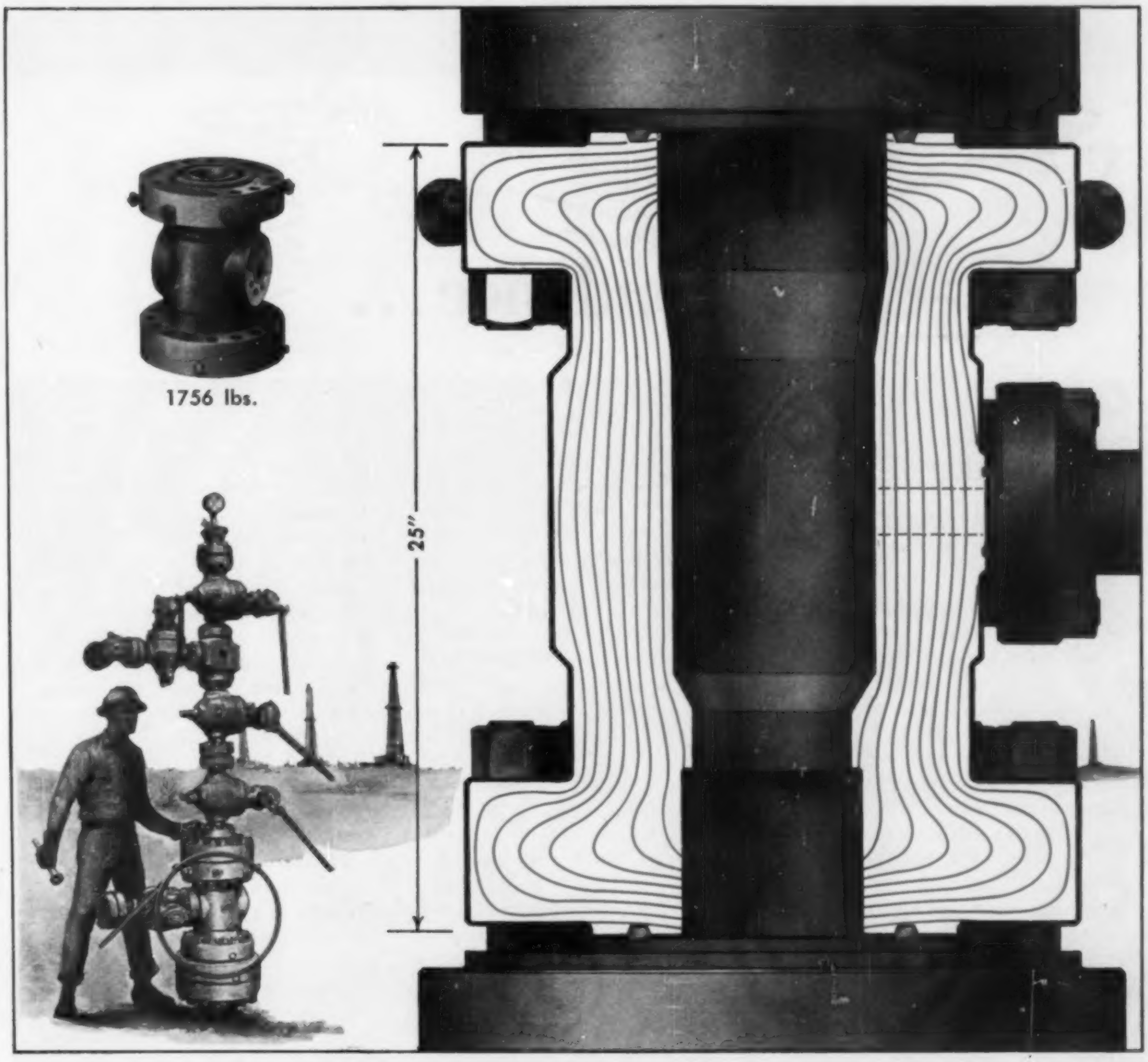
Snakes – One of the most exasperating surface defects periodically encountered in annealing is known as "snakes." This takes the form of a whitish-gray ripply surface at the edges of batch-annealed coils, and is nearly always associated with a D-X atmosphere. Snakes are suspected of being an insoluble iron oxide below the metal surface, arising from oxidation along micro-cracks. The responsible factors are not known. Rolling oils, methane in the furnace atmosphere, high dew points, dirty steel have been suspected, but the role of each remains in doubt since snakes cannot be produced at will in controlled test runs. (Can any reader offer additional information on snaky edges?)

Material Limitations

The final characteristics of annealed cold rolled products – their surface finish, drawing quality, toughness – depend not only on the ordinary variables of time and temperature in annealing, but also on the hidden variables in the prior processing. These hidden variables, as pointed out in two papers by Ralph D. Hindson, assistant chief metallurgist of the Steel Co. of Canada (Hamilton, Ont.) and by Fred L. Otto, metallurgist for Detroit Steel Corp., include such factors as segregation, nitrogen content, finishing and coiling temperatures in the hot mill, cleaning and pickling, and amount of cold work in the final pass.

Many of these, alone or in combination, result in material with undesirable directional properties due to mechanical fibering and to crystallographic preferred orientation. In a fine paper Robert H. Heyer, supervising metallurgist in Armco Steel Corp.'s research laboratories, Middletown, Ohio, reported that crystallographic orientation (texture) is present even after annealing and completely recrystallizing at 1300° F. Texture is undesirable since it may lead to ears on drawn articles. Normalizing completely eliminates earing, as well as mechanical fibering due to precipitated carbides. However, neither process annealing nor normalizing can eliminate or even reduce the fibering which results from drawn-out inclusions.

In a study of the effect of composition on mechanical properties, P. W. Marshall and J. A. Bauscher of U.S. Steel. (*Continued on p.* 142)



SPLIT-DIE STEEL FORGING SOLUTION FOR 15,000 PSI CHRISTMAS TREE PROBLEM

This tubing head spool for oilfield Christmas Trees is still another example of the superiority of Cameron's split-die steel forgings. Thousands of these critical components are on the job almost everywhere oil is produced. The model above must first withstand 22,500 psi test pressure to operate safely at 15,000 psi working pressure — but this is only the beginning. When set, it must be able to support in excess of 300,000 lbs. of heavy steel tubing suspended miles below the earth's surface.

The exclusive Cameron split-die forging process produces two important advantages — 1) Shapes impossible to produce by any other forging method, and 2) Grain flow to meet the most extreme performance demands. The inherent forging advantage of great strength with less mass has been extended to include a new design range. Open center sections, curved or flat surfaces in almost endless variety and odd protrusions are routine design elements when Cameron split-die forgings are specified. These vastly superior ferrous parts are forged to 8,000 lbs. weight.

Cameron is busy today producing split-die forged steel parts for jet engines, guided missiles, atomic reactors and, of course, Cameron Christmas Trees.

Our complete production facilities, from melting of high quality alloy steels to finished machining if desired, allows undivided responsibility — that's another reason why we are serving more customers every month. If you are using castings where forging quality is desired, or if conventional forgings are inadequate, write, call or come by—

Cameron IRON WORKS, Inc.
P. O. Box 1212, Houston, Texas
SPECIAL PRODUCTS DEPARTMENT

Correspondence . . .

Formulation of Heat Resistant Materials

PARIS, FRANCE

Since the war the problem of heat resistant metals has been given intense study because of its importance to gas turbines and missiles for thermal flight, and the search has led from the field of metallic alloys to the branch of powder metallurgy where refractory ceramic particles are bonded into useful shapes by a metallic binder. This may seemingly have complicated the matter very greatly, yet it might be well to recall some general principles, stated by the writer in *Metal Progress* as long ago as August 1932:

To increase the chemical resistance of a metal – for example, its resistance to oxidation – one must assure the presence in sufficient amounts of those elements which are more oxidizable than the host so they may form protective oxides on the surface of the parent material. In addition, such an oxide skin must be heat resistant – that is, refractory against melting, nonvolatile, impermeable and tightly adhering. In other words, the important physical properties of the oxides are those which render them refractory, dense, and nonpermeable.

Consequently, one must first consider the series of refractory products which is utilized in industry and especially in metallurgy. These can have a silicon base (SiO_2), aluminum base (Al_2O_3), or chromium base (Cr_2O_3), to which must be added calcium (CaO) and magnesium (MgO), used as furnace linings in the basic openhearth steelmaking process. In addition, the zirconium-base (ZrO_2), beryllium-base (BeO), and thorium-base (ThO_2) refractories are used in laboratories. More generally speaking, the rare earth oxides find application for incandescent sleeves and filaments.

Supposing now that our interest is in oxidation resistant alloys based on iron, one cannot retain calcium and magnesium in the metal, for they do not alloy with iron. However one obtains with other useful elements – notably chromium, silicon, and aluminum – the essential alloying constituents of industrial steels which have good heat and corrosion resistance. There exists a definite relation between the behavior of these various elements which promote oxidation resistance and their respective atomic weights.

It is possible, by the way, to incorporate several of these elements simultaneously – for instance silicon, chromium, and aluminum – but other considerations must then be taken into account, as summarized below. To be protective, of course, the oxide film which is formed must inhibit further wasting away of the parent metal; otherwise chemical reaction would continue below the surface layer already oxidized.

The following theories are offered for the manner in which this phenomenon may be operative:

1. Oxygen will penetrate through discontinuities or porous spots of the oxidized surface layer if the formation of this layer is not accompanied by a favorable increase in volume. (This was pointed out long ago by Pilling and Bedworth.)

2. The undesired growth of an oxide layer can also occur by diffusion of oxygen (which interferes with the ionic or electrolytic conductivity, as is true of those semiconductors like magnesium whose conductivity increases with increasing temperature). A concentration gradient must exist from where the domain of concentration of the oxidized phase is extended. The best protection is afforded by those oxides which do not form solid solutions or those composed strictly of homopolar bonds. It should also be mentioned that the electrolytic or ionic conductivity varies inversely with the electronic or metallic conductivity.

Trombe has found in his studies of the oxides of lanthanum and titanium that the formation of solid solutions causes a considerable increase in conductivity. Therefore, contrary to what happens in metallic materials, the presence of elements in solid solution enhances the conductivity rather than diminishes it. The solid solutions of zirconium oxide and magnesium oxide contribute an example of substitutional and interstitial solid solution, respectively.

If several different oxides form at the surface of a metallic material due to selective corrosion, it is important that they do not form solid solutions.

Those principles which concern the heat resistant characteristics of metallic materials are evidently equally applicable to resistance to sulphurization at elevated temperatures – a very important matter in the petroleum industry. Here, however, the heat of formation must be considered, the density, the conductivity, and the formation of solid solutions of sulphides.

ALBERT M. PORTEVIN
Member of the Institute

Probabilities in Fatigue Testing

CAMBRIDGE, MASS.

The scatter problem in fatigue may not be quite as serious as Professor Richart indicated in the article of the above title in *Metal Progress* for August 1957, p. 111. See, for example, the S-N-P curves for 4340 steel given by Cummings, Stulen, and Schulte in *Transactions*, 1957, p. 482. I have found in lathe-turned aluminum alloy 7075-T 6 that the standard deviation in strength for a given life was only 0.9 to 1.5% (95% confidence) of the mean strength. Even in ZK 60-T 5 magnesium the value has been reported to be only 3 to 5% (95% confidence).

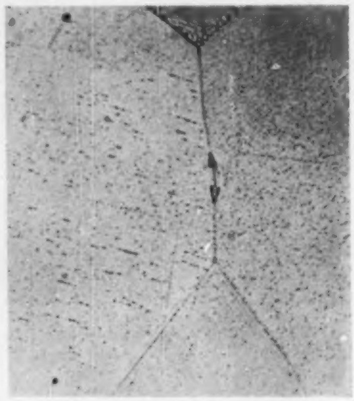
I also question his requirement that for endurance life at least 20 (and preferably 50 to 100) specimens must be tested at each stress level. The number of specimens merely determines the precision of the estimate, not what can or cannot be estimated. Small-sample techniques are available for estimating to any desired level of confidence either the mean life or the life to be exceeded by some certain percentage of the specimens. To be sure, the fewer the specimens, the broader the confidence interval, but there is little point in obtaining a statistical estimate which is much more precise than one's knowledge of the effect of production and environmental factors which affect a part in service differently from a part tested in the laboratory.

FRANK A. MCCLINTOCK
Assoc. Prof. of Mechanical Eng.
Massachusetts Institute of Technology

Grain Boundaries Positive

PITTSBURGH

In the course of investigating a complicated heat treatment on an exotic alloy, a structure was revealed that metallography professors the world over have been searching for since time immemorial. These kindly gentlemen need never again fear



The Arrows Point to the Grain Boundary. 250 ×

that the class will miss the point when, on observing a photomicrograph for the first time, they are told to look for grain boundaries. All that need be done is to show the unretouched micrograph above and say, "The arrows point to the grain boundary."

R. E. JOHNSON
Atomic Power Division
Westinghouse Electric Corp.

Personal Mention

Francis B. Foley

Frank W. Glaser

FRANCIS B. FOLEY has accepted a position as executive metallurgical engineer with Pencoyd Steel and Forge Corp., Philadelphia. This marks the renewal of the metallurgical association of Mr. Foley and **Adolph O. Schaefer**, president of Pencoyd, both of whom spent many years at the Midvale Co. in Philadelphia.

In 1949 Mr. Foley left Midvale, where he had been in charge of research, to become consulting metallurgist in charge of the steel section of the International Nickel Co.'s Bayonne, N.J., laboratory. In 1953 he transferred to the stainless steel division of the development and research department of Inco in the same capacity and he has been there ever since. Last July, as a step toward retirement, he scheduled his work for Inco on a part-time basis. The balance of his time will now be taken up with his duties at Pencoyd.

His extracurricular interests are widespread, and he has held numerous offices in the technical societies to which he belongs. He was national president of in 1947.

In addition, he has been chairman of the Franklin Institute Clamer Medal Committee for some years, and has served as chairman of many technical committees, including a stint as chairman of the Iron and Steel Div. of the American Institute of Mining, Metallurgical and Petroleum Engineers.

FRANK W. GLASER, executive vice-president and general manager of Alloy Precision Castings Co., Cleveland, a subsidiary of the Mercast Corp., has been named a vice-president of the parent company. Although Mr. Glaser will still devote the major portion of his time to the Alloy Precision Castings Co., he will also operate from Mercast's New York and California offices.

Mr. Glaser joined American Electro Metals Corp. in 1946, rising to assistant to the president and finally vice-president and technical director of the company before his resignation in 1955 to join Alloy Precision Castings. During his years at American Electro Metals, he enrolled in evening courses at the College of the City of New York and in 1949 received his Bachelor's degree. He also studied at the Polytechnic Institute of Brooklyn, where he received his Master's degree in 1951, and at the Polytechnic Institute of Zurich in Switzerland.

His society memberships include the American Institute of Mining, Metallurgical and Petroleum Engineers and the British Institute of metals.

P. D. Deeley has been named sales engineer for Electro Metallurgical Co., New York, a division of the Union Carbide Corp. Mr. Deeley, a graduate of Michigan College of Mining and Technology, is assigned to the Pittsburgh region.

J. D. Loveley has been named to the newly created position of assistant chief engineer in charge of vehicle air conditioning at Chrysler Corp., Detroit. He has been associated with Chrysler since his graduation from the University of Detroit in 1935, and prior to his new post had responsibility for all engineering activities at the Airtemp division of the company in Dayton, Ohio. Mr. Loveley also served as chairman of the Dayton Chapter in 1948-49.

Robert E. Savage has been placed in charge of the distributor sales section of the nickel department of the International Nickel Co., Inc. Joining the ductile iron section of the development and research division in 1949, he was transferred to the nickel department last year.

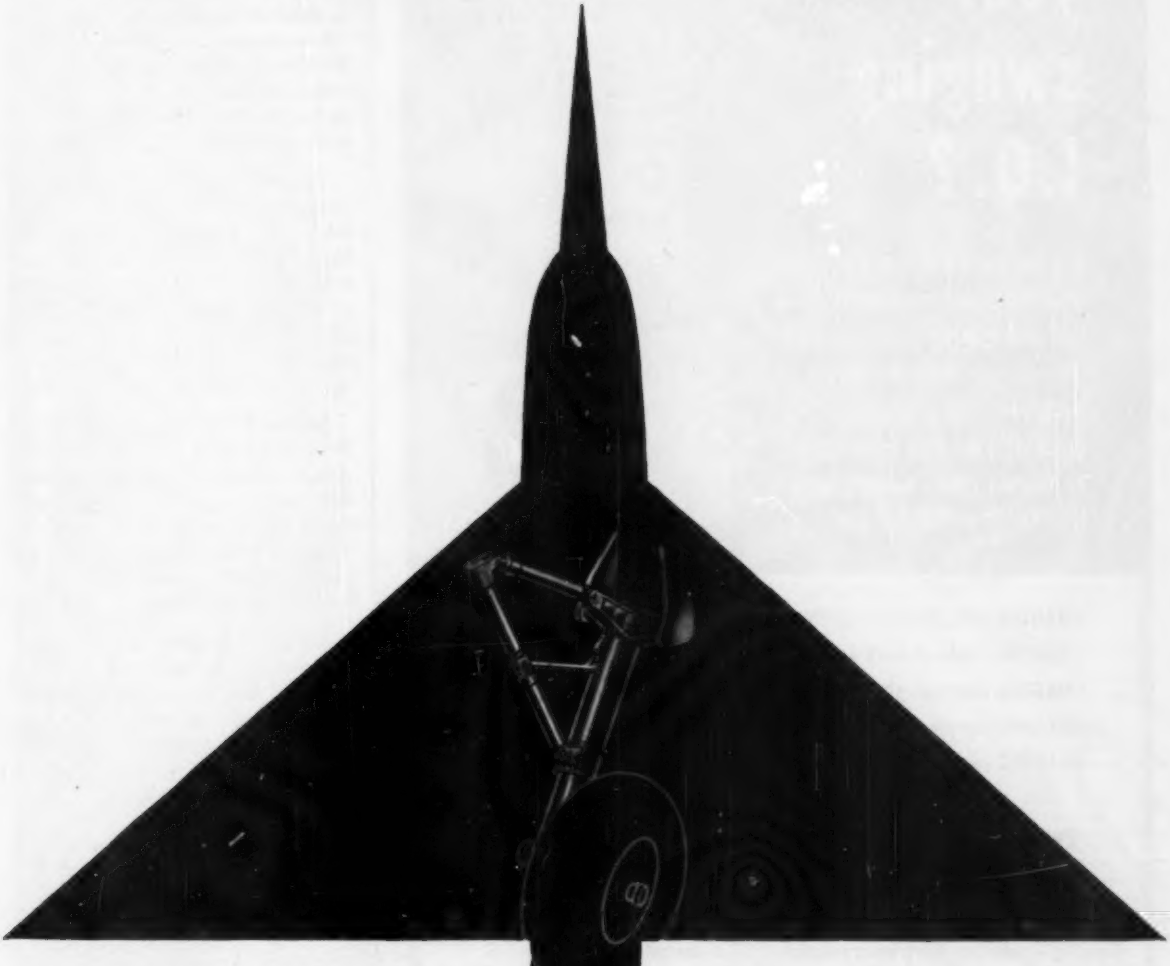
Robert B. Gordon has resigned as manager of the core engineering department, Westinghouse Bettis Atomic Power Division, Pittsburgh, to accept a position as nuclear specialist in the Atomics International Div. of North American Aviation, Inc., Canoga Park, Calif.

Robert E. Fleming has been elected executive vice-president of the Industrial Heating Equipment Association to succeed **Carl L. Ipsen** who has retired. Mr. Fleming, who has been active in government work and industry in the metalworking equipment field, comes to I.H.E.A. from the metalworking equipment division of the Business and Defense Services Administration. He has just returned from India where he served as a member of the United States Machine Tool Delegation.

Herbert J. Kaplan has joined the Bettis Plant atomic power research laboratory of Westinghouse Electric Corp. in Pittsburgh and is engaged on engineering research and development.

H. G. Thompson has resigned as quality control manager with the Murray Ohio Mfg. Co., Cleveland, to accept the position of chief inspector with the John Oster Mfg. Co., Milwaukee. Mr. Thompson had been with Murray Ohio for the past four years and prior to that, was director of quality control, Master Electric Co., Dayton, Ohio.

Crucible UHS 260 steel makes it 15% lighter



Crucible UHS 260 alloy steel was designed specifically for use in the 260,000/280,000 psi ultimate tensile strength range. That's why aircraft manufacturers rely on it extensively for aircraft parts such as landing gears. Now it's bringing definite advantages in applications where more properties other than just high strength are of primary concern.

Take, for example, parts where weight and cross-sectional dimensions must be limited. In such parts, Crucible UHS 260 pays off because under load it is about 15% lighter than high-strength aluminum alloys. Savings like this in weight and space make Crucible UHS 260 highly practical for a wide variety of applications where high strength, as such, is not the primary requirement.

To check the other properties of Crucible UHS 260 alloy steel against your own particular problems, write for Data Sheet to *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Personals . . .

Robert F. Packard ⊕ has been released from the U.S. Army and is now in the nuclear products division of the Metals and Controls Corp., Attleboro, Mass. His Army assignment was as metallurgist in the Pitman-Dunn Laboratories of the Frankford Arsenal, and prior to his tour-of-duty in the armed forces, he was on the research staff of Massachusetts Institute of Technology.

Richard A. Harlow has joined the Bettis Plant atomic power research laboratory of Westinghouse Electric Corp. in Pittsburgh. Mr. Harlow, who recently received his bachelor of science degree from Michigan State University, will be engaged in engineering and development work on nuclear cores for atomic reactors.

Martin L. Anderson, Jr., ⊕ has been transferred from Birmingham, Ala., to Atlanta, Ga., as general products sales engineer for Ingersoll-Rand Co., covering the Georgia and South Carolina territory. He was previously senior office engineer for the company's Southeast territory.

Arthur Townhill ⊕ has joined Rocketdyne Div. of North American Aviation, Inc., as a specialist in casting practices. He formerly was concerned with die casting and permanent mold casting at Thompson Products, Inc.

Ford W. Knight ⊕ has resigned from the engineering assistance section of E. I. du Pont de Nemours & Co., Inc., to join the advanced reactor group of Atomic Power Development Associates, Inc., in Detroit. He is presently on loan from the organization to the Los Alamos Scientific Laboratory as an industrial staff member for one year.

James O. Jepson ⊕ is now a chemist at the University of California radiation laboratory in Livermore, Calif.

John E. Ashley ⊕, formerly a senior metallurgist with Reed Roller Bit Co., Houston, Tex., has been named senior metallurgist for the stress analysis group of Pratt & Whitney Aircraft's materials development laboratory in East Hartford, Conn. Later, Mr. Ashley will be transferred to Pratt & Whitney's new Florida testing facility.

Personals . . .

Willy Form, upon completion of his work towards a Ph.D. degree at the University of Montreal, accepted an appointment as an assistant professor of metallurgical engineering at Case Institute of Technology, Cleveland.

Leonard L. Young has changed his position from laboratory technician for Eastern Malleable Iron Co. to sales and service engineer in the Connecticut and Rhode Island areas for the A. F. Holden Co.

Jesse B. Goodgame has accepted the post of manager, sales and engineering for the Charlotte, N.C. office of the Ramsey Chain Co.

Leonard B. Gross has joined the staff of the product and development department of Electro Metallurgical Co., Niagara Falls, N.Y., a division of Union Carbide Corp.

C. A. TenHoopen, Jr., has transferred to Baltimore, Md., as office manager of the Baltimore district of U.S. Steel Supply Div., U.S. Steel Corp. Prior to his promotion, he was resident salesman in the York-Lancaster, Pa., area.

Howard A. Stai has been appointed products manager for the Seattle, Wash., steel service plant of J. T. Ryerson & Son, Inc. He has had more than eight years experience in the Ryerson organization, and most recently served as manager of tubing and cold finished bar sales.

John C. McDonald has accepted the job of staff scientist for research and development, missile systems division, Lockheed Aircraft Corp., Palo Alto, Calif. Before joining Lockheed, he was affiliated with the Dow Chemical Co. in Palo Alto as assistant technical director of the magnesium department.

W. D. Labrum has been transferred from the Office of the Assistant Industrial Manager, U.S. Navy, in Astoria, Ore., to Charleston Naval Shipyard, where he has been assigned as the shop superintendent.

Jeffrey Funsch, a recent graduate of Lehigh University, has joined Crucible Steel Co. of America as a metallurgist in the Sanderson-Halcomb Works in Syracuse, N.Y.

Personals . . .

Oscar Marzke ⊕ was recently made a vice-president of the United States Steel Corp., in charge of fundamental research. Dr. Marzke, a past chairman of the Washington Chapter ⊕, was previously director of research of the Naval Research Laboratory in Washington, D.C.

K. C. Chatterjee ⊕, who recently completed his master's degree in mechanical engineering at Oregon State College, is now working with Boeing Airplane Co. as a tool engineer in the tool and production planning unit, working on the Boeing 707 commercial jet transport.

E. D. Cowlin ⊕ has been elected a director and vice-president in charge of sales for Quality Fasteners, Inc., of Kalamazoo, Mich. In addition to his new positions, Mr. Cowlin will also serve as a sales executive with Moore & Steele, Owego, N.Y. He retired from the post of general manager of the Reliance Div., Eaton Mfg. Co., Massillon, Ohio, in September after 33 years with the company.

Vincent De George ⊕ has joined the Bettis Plant atomic power research laboratory of Westinghouse Electric Corp., Pittsburgh, where he is now engaged on metallurgical engineering projects for nuclear cores for atomic reactors.

Gordon C. Farnsworth ⊕, chief metallurgist and laboratory engineer at General Motors Corp.'s Truck and Coach Div., Pontiac, Mich., retired from the company after 38 years of service. For the last 25 years he has been associated with the Truck and Coach Div.

Harold C. Templeton ⊕ has taken a post as chief metallurgist for Alloy Steel Products Co., Linden, N.J. He was formerly chief metallurgist for the Lebanon Steel Foundry, Lebanon, Ohio, and before that was affiliated with Babcock & Wilcox Co., Barberton, Ohio.

Marshall C. Brown ⊕ has been transferred to the Buffalo, N.Y., district office of Kaiser Aluminum & Chemical Co., as district engineer. Before his transfer, he was assistant engineer in the company's New York district.

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Personals . . .

T. I. McClintock has been transferred to the Vernon, Calif., works of the Aluminum Co. of America as assistant chief works metallurgist. He was formerly staff metallurgist in Alcoa's central metallurgical division in Pittsburgh, and served as chairman of the Pittsburgh Chapter in 1955-56.

R. W. Dickinson has left the General Atomic Div. of General Dynamics Corp., San Diego, Calif., to join Atomics International Div., North American Aviation, Inc., Van Nuys, Calif., as chief project engineer of the sodium graphite reactor program.

Wallace F. Sheely, after receiving a Ph.D. degree from Rensselaer Polytechnic Institute, has started work as a research engineer for the Metals Research Laboratory of the Electro Metallurgical Co., Niagara Falls, N.Y.

Lawrence G. Wexlin, who recently received his master of science degree from Lehigh University, is now working in the carbon sheet and strip division of the Applied Research Laboratory of U.S. Steel Corp. in Monroeville, Pa.

Vernon H. Patterson has joined the sales staff of Texas Foundries, Inc., Lufkin, Tex., as sales manager. For the last eight years, he was employed by Climax Molybdenum Co., first as a metallurgical engineer in the Detroit district and more recently as manager, foundry sales, with headquarters in New York.

William Durako was recently appointed service metallurgist for the Detroit area by Crucible Steel Co. of America.

William H. H. Wyatt has left his position as service engineer with the Pacific Scientific Co. to accept the post of maintenance engineer with Downey Steel Treating Co., Downey, Calif.

Ernst M. Goldstein resigned from his position as group leader with the Nickel Processing Corp., Montclair, N.J., to join the research laboratory of Metal & Thermit Corp. in Rahway, N.J. Mr. Goldstein will head the corporation's recently expanded metallurgical laboratory.

Personals . . .

Frank Elston Binns has left the nuclear division of the Martin Co., Baltimore, Md., to accept a position as a research and development engineer at the nuclear products division of the Metals and Controls Corp. in Attleboro, Mass.

Martin S. Farkas is now employed in the reactor metallurgy division of Battelle Memorial Institute, Columbus, Ohio, as principal metallurgist.

H. I. Raiklen has been placed in charge of patent technical liaison for the Brookhaven National Laboratory, Upton, L.I., N.Y. Before his present assignment, he was advance research engineer in nuclear metallurgy for Sylvania-Corning Nuclear Corp., Bayside, N.Y.

Thomas G. Gascoigne has joined the West Coast staff of Avildsen Tools and Machines, Inc., Glendora, Calif., as chief service engineer. Mr. Gascoigne has had 22 years experience in aircraft manufacture on the West Coast, including the last five years in tooling research and development for Convair, a division of General Dynamics.

George A. Goepfert is presently employed as metallurgical salesman for the California Alloy Products Co., Los Angeles.

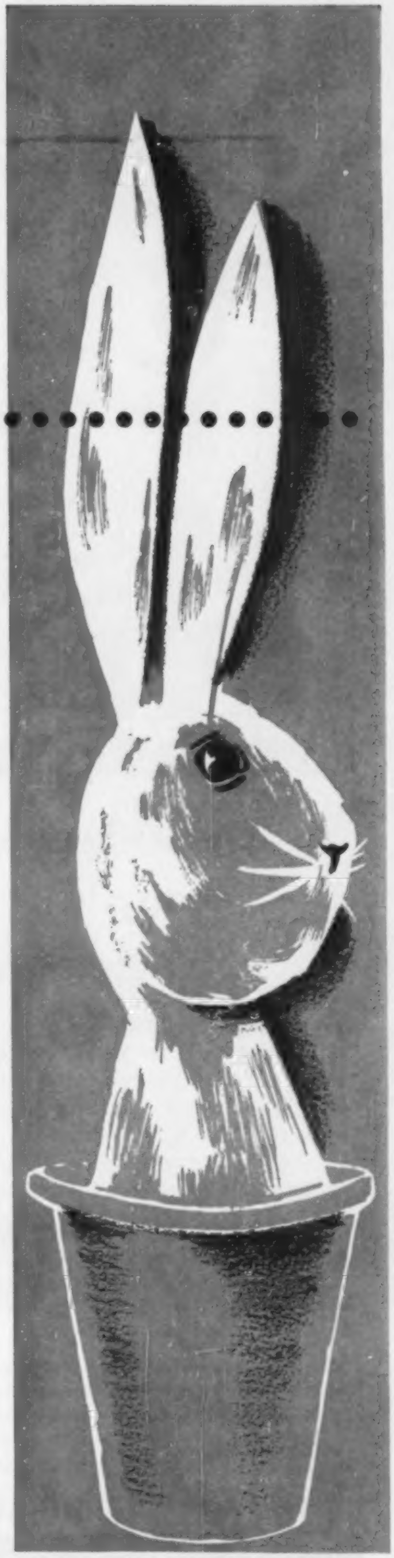
Edward B. Tilley, formerly process engineer with Northrop Aircraft, Inc., has taken a position as chief metallurgist with Pacific Alloy Engineering Corp., San Diego, Calif. Mr. Tilley's responsibilities include supervision of the company's chemical, mechanical and metallurgical control operations.

John A. Alexander has accepted a position as assistant research metallurgical engineer with the Metals Research Laboratory at Carnegie Institute of Technology, following a year of graduate work at the institute. He was formerly employed by Inland Steel Co. and Westinghouse Electric Corp.

Andrew T. Kemp has been transferred from his post as branch manager of the Baltimore, Md., warehouse of A. M. Castle & Co., Chicago, to the position of manager of the Chicago district.

PERMABRASIVE is the only pearlitic malleable iron shot and grit on the market. Pearlitic malleable iron is made with the proper analysis and controlled heat treatment. The result is malleable iron with a more durable structure and, in abrasives, "pearlitic" means a greater resistance to break down, longer life, greater cleaning ability with all the advantages of lower abrasive costs, lower maintenance costs, faster cleaning!

"Pearlitic"...................... is a magic word!



National Metal has been making pearlitic malleable shot and grit for several years. Permabrasive—the only pearlitic malleable shot and grit—has been a pioneer in the field of premium quality abrasives and has saved thousands of dollars for hundreds of foundries!

Sure, Permabrasive pearlitic malleable shot and grit costs a little more per ton than ordinary annealed abrasives. That's because it costs more to make. But its use has snow-balled, because it saves money on abrasives used and cuts maintenance costs substantially. *Your* savings are *guaranteed in writing* when Permabrasive goes to work in your blast cleaning room.

TIRED OF TESTING?

No one blames you for being tired of making endless, complicated tests to prove every claim that comes along! We suggest you use a "time-meter"—and reduce your operation to simple "wheel-hours." An office boy can keep the records—doesn't interfere with operations—gives you all the dope you need on abrasive consumption, evaluating materials and equipment parts, and furnishes excellent cost records. Write for free folder: "Tired of Testing!"

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Personals . . .

J. O. Cavanagh ⊕ has been elected vice-president in charge of research for Alloy Rods Co., York, Pa. Joining the company in 1951, Mr. Cavanagh was formerly director of research and development.

H. M. Webber ⊕ has been appointed manager of process engineering for Harper Electric Furnace Corp., Buffalo, N.Y. He joined the company after 30 years as an application and process specialist with the industrial heating department of the General Electric Co.

David Swan ⊕, director of research of Metals Research Laboratories, Electro Metallurgical Co., Niagara Falls, N.Y., a division of Union Carbide Corp., has been named vice-president, research and development, for the Linde Co., another Union Carbide division. Mr. Swan has been with Electromet at the New York and Niagara Falls offices since 1946, and has been director for the last two years.

Richard B. Kropf ⊕ has been appointed supervisor of development activities in the automotive industry for International Nickel Co., Inc., New York. Mr. Kropf, who will make his headquarters in Detroit, will devote his attention to the engineering materials used in construction of civilian and military vehicles in all producing centers throughout the country. Coming to Inco in 1945, he was assigned to the Detroit technical field section in 1951.

George L. Durfee ⊕ has been promoted to assistant chief metallurgist of the Worcester plant of the Wyman-Gordon Co., Worcester, Mass. He was formerly research associate in the research and development department.

Philip Edward Armstrong ⊕ has become a member of the staff of the University of California, engaged in metallurgical research at the Los Alamos Scientific Laboratory, Los Alamos, N.M. Dr. Armstrong recently received his Ph.D. degree in metallurgy from Iowa State College, Ames, Iowa, while working for the Ames Laboratory of the U.S. Atomic Energy Commission. His doctorate degree was the first to be granted in metallurgy by Iowa State College.

Personals . . .

Witold Wojcik has left the Ontario Research Foundation in Toronto, Ont., and joined the staff of Jones & Laughlin Steel Corp. He will act as research metallurgist at the Graham Laboratory of the research division in Pittsburgh.

Eugene P. Veilleux, after his release from the U.S. Air Force, accepted a position with the Raytheon Mfg. Co., Lowell, Mass., in the missiles systems division as a standards engineer.

M. C. Huffstutler, Jr., has left the metallurgical laboratory of Dow Chemical Co., to join the faculty of the department of mining and metallurgy at Texas Western College as assistant professor.

Paul C. Holland is the new general manager of National Precision Casting Corp., Paoli, Pa., a subsidiary of the Beryllium Corp., Reading, Pa. As general manager, he will have full responsibility for the operation of the company's new plant in Paoli. Mr. Holland formerly was affiliated with the parent company, the Beryllium Corp., as product manager.

R. D. Chapman has been named assistant chief engineer of the metallurgical research department of Chrysler Corp., Detroit. Mr. Chapman has been affiliated with Chrysler since 1939 when he joined the metallurgical research laboratories of the engineering division, and held the post of managing engineer of the metallurgical research department before his new appointment.

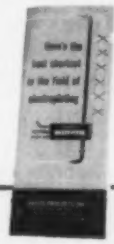
Vikash C. Kashyap is now working with Hindustan Steel Private Ltd. as a junior engineer. He has been sent by the Ministry of Steel, Fuel and Mines of the Government of India to undertake special training at the Bethlehem Steel Co. and Lehigh University. This program is financed by the Ford Foundation.

Edward L. Harmon, Jr., is now a research metallurgist at the Metals Research Laboratories of the Electro Metallurgical Co., Niagara Falls, N.Y. Formerly a research assistant at Case Institute of Technology, he received his Ph.D. degree in June.

Here are 6 good methods for making easy jobs out of hard ones

1. For precleaning in the plating shop

Oakite precleaners quickly remove the toughest soils that work their way into the plating shop. This 44-page illustrated booklet gives useful information about tank precleaning on pages 6 to 11 and machine precleaning on pages 11 to 14.



2. For descaling and derusting steel

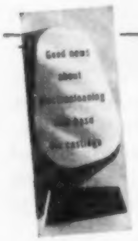
Oakite Rustripper saves time by removing heat scale and rust in the same operation that removes oil. Alkaline pickling with Rustripper avoids hydrogen embrittlement, etching of machined surfaces and other disadvantages of acid pickling.

3. For electrocleaning steel

Oakite Composition No. 90 is a reverse-current cleaner with great ability to remove oils, smuts and other objectionable films that interfere with good electroplating. Solutions have high conductivity and long service life. Controlled foaming eliminates explosion hazards.

4. For electrocleaning brass

Oakite Composition No. 191 scientifically protects brass from the oxygen that tarnishes during the use of reverse current. Solutions have high conductivity, long life and high tolerance for chromic acid carried over by plating racks.



5. For electroconditioning zinc die castings

Oakite Composition No. 95 anodically removes all films that would impair the brightness of the plate. Under-surface shadows and anodic blackening are eliminated. A manufacturer of die-cast hardware reported "No. 95 cut our cleaning rejects more than 95%."

6. For preventing water spots

Oakite Rinsite causes rinse water to drain rapidly, leaving the plated metal bright, sparkling and completely free from water spots and tarnish. Rinsite is also good as a rust preventive in rinses between barrel finishing operations.

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2. "Here's the best shortcut in the field of electroplating"
3. "Four good steps toward better electroplating on steel"
4. "What's NEW in electrocleaning brass and other copper alloys"
5. "Good news about electrocleaning zinc-base die castings"
6. "Put SPARKLE in your rinse water with Oakite Rinsite"

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Roderick L. Harper, Executive VP and H. M. Webber, new Manager of Process Engineering, discuss brazing furnace during construction.

Top brainpower gives Harper Furnace edge in brazing, sintering fields

H. M. Webber, noted authority on furnace brazing and protective atmospheres, joins company . . . spearheads expanded program for development and application of brazing and sintering furnaces.

"Brainpower is the key to a company's position. It provides the only true foundation for strength, growth and ultimate leadership." That's the opinion of Roderick L. Harper, executive vice president of Harper Electric Furnace Corporation, who has just announced the appointment of H. M. "Pete" Webber as new Manager of Process Engineering.

The selection of Mr. Webber for this post reflects Harper's policy of filling top positions with top caliber men. With over 30 years' experience in process and application engineering behind him, "Pete" Webber is recognized as an outstanding authority on furnace brazing, sintering and protective atmospheres.

A prolific writer of numerous articles and technical papers, he has co-authored the book "Protective Atmospheres," and produced one of the most complete treatises ever published on furnace brazing. Recognized throughout the industry as an eminently well-informed lecturer and consultant, soft-spoken "Pete" Webber displays a keen perception of customers' problems that inspires immediate confidence.

In his new position, he will serve as a consultant to Harper customers on the proper selection and operation of high temperature brazing and sintering furnaces. Industrialists are invited to contact "Pete" Webber or other specialists on the Harper staff for information or assistance with their specific problems.

Harper Electric Furnace Corporation manufactures a complete line of electric furnaces for continuous brazing, sintering, bright annealing, forging and research, as well as electric kilns for the ceramic and electronic industries. Its general offices are located at 110 Pearl Street, Buffalo 2, N. Y.

Personals . . .

Lester Hill has returned to the Crucible Steel Co. of America as assistant sales manager of the Pittsburgh sales division. Mr. Hill was metallurgical engineer at Crucible's Midland, Pa., plant for 14 years until 1955, when he joined the Vulcan Crucible Steel Div., H. K. Porter Co., Inc., in Aliquippa, Pa. He is currently serving as chairman of the Pittsburgh Chapter.

George J. Oswald, a charter member of the Dayton Chapter, has been cited as an "outstanding member" by that chapter for his work in copper brazing and, more recently, high-strength powdered metal parts. He organized the metallurgical laboratory at the National Cash Register Co. and continues to direct its activities.

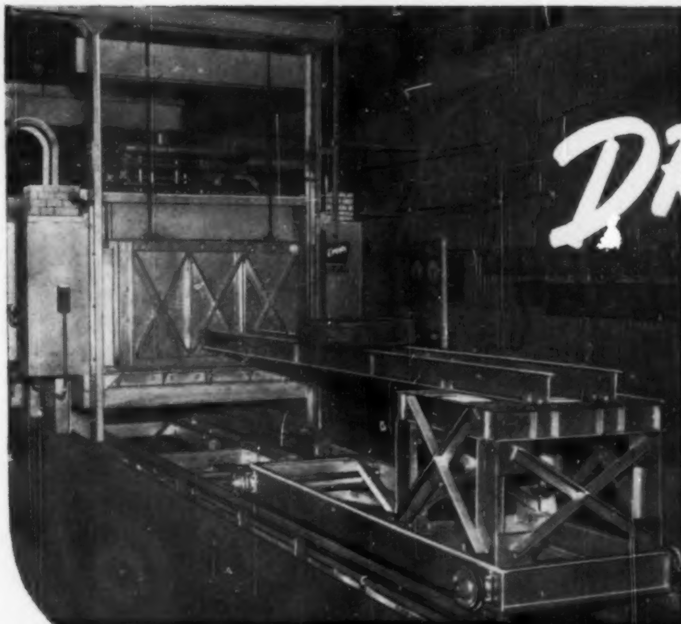
Harshad J. Bhatt has been appointed a junior technologist in the chemical metallurgy division of U.S. Steel Corp.'s Applied Research Laboratory in Monroeville, Pa. Mr. Bhatt came to the research center from Union Carbide Corp.'s South Charleston, W.Va., plant.

Gordon C. Williams is on leave from the department of chemical engineering at the University of Louisville for one year to participate in the E. I. du Pont de Nemours, Inc., engineering department "Year in Industry" program.

R. H. Reiber, formerly assistant manager of the Boston district of the U.S. Steel Supply Div. of U.S. Steel Corp., has been named Boston district manager. He has also served as assistant manager in the division's Pittsburgh district.

Charles M. Beeghly, formerly vice-president and general manager of the Cold Metal Products Co., Youngstown, Ohio, has been named president of the strip steel division of Jones & Laughlin Steel Corp. in Youngstown.

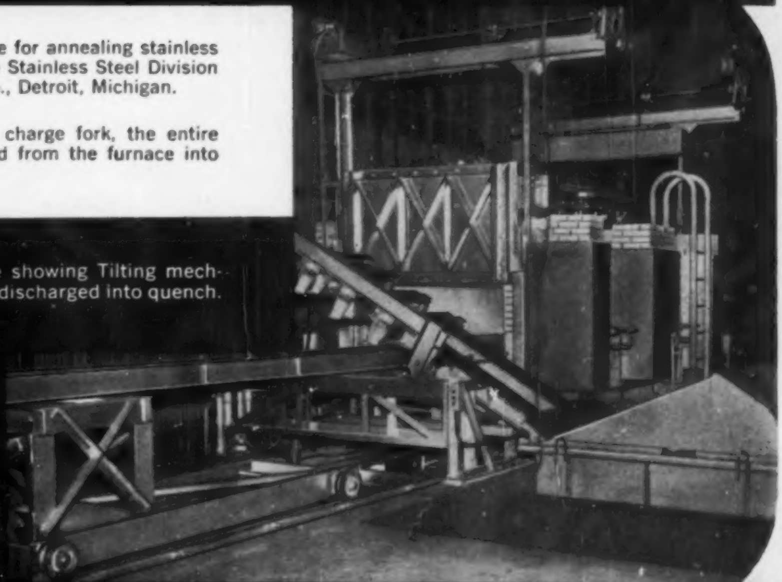
Joseph B. Kushner, director of the Joseph B. Kushner Electroplating School, Stroudsburg, Pa., has been awarded a Ph.D. degree in metallurgical engineering by Lehigh University. Prior to organizing the school ten years ago, Mr. Kushner was a consultant to the metal finishing industry.



DREVER Stainless Wire Coil Annealers

Charge end of a Drever furnace for annealing stainless steel wire coils installed at the Stainless Steel Division of Jones & Laughlin Steel Corp., Detroit, Michigan.

After operator places coil on charge fork, the entire operation into the furnace and from the furnace into the quench is automatic.



Discharge end of furnace showing Tilting mechanism after coil has been discharged into quench.

Two quenches are supplied; water quench for 300 series and oil quench for 400 series.

Drever's gas-fired coil annealing furnace is designed to handle (4) 250 lb. coils of wire per hour. Coils vary from 36" to 48" O.D. in size and from 200 to 250 lbs. in weight.

Uniform and rapid heating of coils is accomplished with a minimum of scale formation.

Consult Drever engineers on your stainless wire, rod, bar, sheet, plate and strip heating problems.

DREVER COMPANY

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37

Digests of Important Articles

Larger Precision Titanium Forgings

Digest of "Present Limitations and Future Possibilities in Titanium Forgings", by J. J. Russ, paper presented at the ⊕ Titanium Conference, Los Angeles, March 25-29, 1957.

FABRICATION of titanium and its alloys has progressed considerably during the past three years.

Difficulties and inconsistencies which existed a few years ago have largely disappeared due to high standards of uniformity of composition, as well as internal and external quality. Much of the increase in use of titanium in aircraft stems from the fact that now the material is consistent enough in properties. Furthermore, production problems in machining, mechanical joining, welding, cold forming, and other processes have been minimized or overcome.

Some problems still exist. Of major concern to forgers is the problem of surface quality and the contamination level of incoming material.

In early 1955 significant improvements were made in the control of hydrogen as a contaminant. While the average level is below the 125 ppm. usually specified, it is not adequate to meet the new and more stringent specifications calling for 100 ppm. maximum.

Because the normal hydrogen pick-up during forging of parts over 1-in. cross section is from 20 to 30 ppm., and much higher for smaller sizes, it is necessary for forge shops to order material with severely restricted hydrogen levels to meet specifications without the need for vacuum annealing. Combustion control aids in keeping the hydrogen contamination level at a low rate. By maintaining an oxidizing balance in the gas mixture, and a low moisture content, hydrogen pick-up can be restricted to the previously indicated levels.

Experience in the forging of titanium has indicated that a much greater force is required to deform titanium than to forge an alloy steel. Tests indicate that titanium is almost twice as difficult to move as A.I.S.I. 4340 and compares with Inconel "X" in resistance to deformation. On the other hand, titanium has reasonably good spreading characteristics, yet it resists movement into ribs and bosses. A common aircraft forging containing several bosses and ribs is produced in 4340 steel on a 4000-lb. steam hammer. Producing it in a 5% Cr, 3% Al titanium alloy, using the same dies, required a 12,000-lb. steam hammer. Our experience shows that a 3 to 1 unit size increase is necessary when forging a titanium element in dies previously designed for forging steel.

We have determined the force required to forge various grades of titanium to precision dimensions with approximately 0.100-in. web thickness. Commercially pure titanium requires 40 to 50 tons per sq. in. forming pressure; C-130 AM, Ti-140 A and Ti-150 A, 75 tons per sq. in.; Ti-155, 85 tons per sq. in.; RS-140 X, 6Al-4V and 7Al-3Mo, 100 tons per sq. in. For comparison 4340 steel under similar conditions requires about 20 tons per sq.in.

In developing comparisons between titanium and 4130 steel for the production of semi-precision and precision forgings we find that titanium parts in these categories are restricted to two-thirds the size of steel forgings; internal and external draft angles must be greater for titanium, minimum rib widths and corner radii should be slightly greater in titanium, as should minimum fillet radii.

Considerable optimism is shown over the future production of larger precision forgings in titanium. Necessary steps are known, as well as the types of equipment and tool and die steels to do an adequate job. Future possibilities from a production standpoint look promising. With current progress in heat treatable alloys such as 7Al-3Mo or 7.5Al-4Mo, there should be many new uses for titanium forgings.

T. H. DUMOND

Study of Steel Ingot Solidification

Digest of "The Effects of Gravity in the Solidification of Steel", by B. Gray, *Journal*, Iron and Steel Institute, April 1956, Vol. 182, p. 366-374.

THIS PAPER presents a detailed study of, among other things, the crystal structures, segregation and piping, in the cross section of seven acid steel ingots containing 0.35% carbon. Ingots were 6 in. diameter, 30 in. long, and were bottom poured into dried sand molds. The variations in casting techniques were:

1. First ingot was a "normal" casting – bottom-run, top fed, upper surface of head cooled to atmosphere.
2. Same as for ingot No. 1, but upper surface heavily chilled by the insertion of five iron bars into the top of the feeder head, which was also side-chilled.
3. Shorter sink head, 6 in. high, molded into an exothermic sleeve. Upper surface of head froze over 5 min. after pouring.
4. Same as for ingot No. 3, but with exothermic powder sprinkled on surface of sink head after pouring, thus delaying formation of solid skull for 30 min. Ingots No. 3 and No. 4 were poured from a common runner.
5. Same as ingot No. 3.

Ingot Solidification . . .

6. Exothermic powder covering used on head but no exothermic molded sleeves on side of head.

7. Same as ingot No. 6 with additional cover of exothermic powder 5 min. after pouring. Ingots No. 6 and No. 7 poured from a common runner.

The cold ingots were cut in the middle longitudinal plane and examined by sulphur printing and by deep etching. Drawings of these cross sections are shown and the reader can observe more in these than he will get from the highly involved accompanying discussion.

Ingot No. 1 exhibited coarse dendritic columnar crystals on all sides from top to bottom, deep-seated central piping as low as 10 in. from the bottom, large pipe at the bottom of sink head and in the head itself. Top chilling of ingot No. 2 caused a large decrease in thickness of the columnar crystal skin and greatly reduced center piping. Ingots No. 3 and No. 5 had excellent structure with very thin columnar skin, no center piping, with most of the cross section made up of small equiaxed nuclear crystals. These showed how the exothermic head sleeves and exothermic powder cover kept the metal in the sink head molten for a much longer time, thus feeding liquid metal continuously to the ingot freezing below the sink head. Ingots No. 4, 6 and 7 were similar but inferior to ingot No. 3 as all showed some deep-seated center piping.

Deep etching and sulphur prints showed typical sulphur segregation around pipe cavities and a long discussion of the complicated reactions occurring in the freezing of steel follows with a review of some of the important older theories of ingot structures.

Modifications of the thermal conditions in the feeder heads of long, vertically poured steel castings leads to important changes in the mechanism of crystal growth in the solidifying steel. These changes are effective in the earliest stages of freezing, and can only be caused by convection currents.

Nuclear and equiaxial dendrite crystals are considered to originate from identical crystalites, and the difference in their shapes is attributed to the differences in the environment in which they grow.

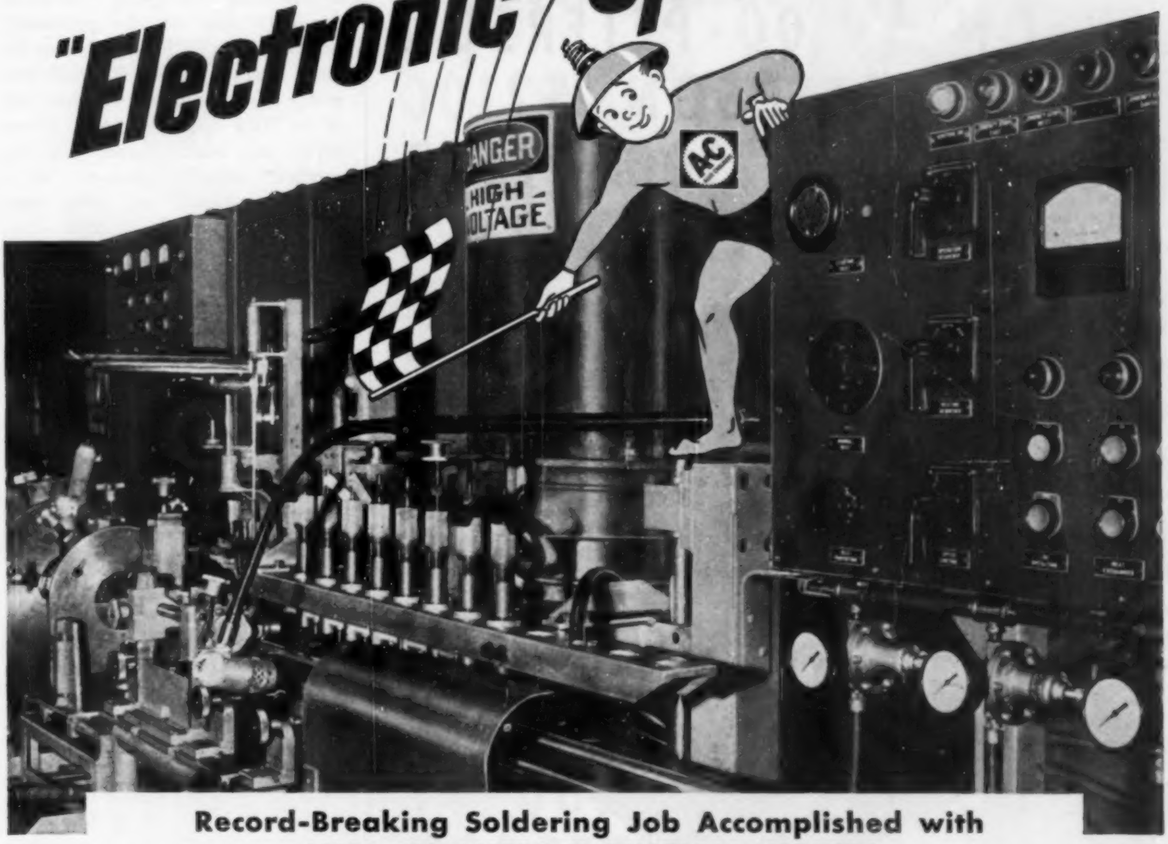
In nearly all the mechanisms proposed in the past, a major difficulty has been to explain how the heat of freezing is dissipated in equiaxial formation. It is seen here that in vertical castings, nearly all such freezing takes place in the current at the walls so that the heat is dissipated through them. That explanation also shows why, in nuclear crystal formation, the columnar wall growth is severely checked.

V-segregates are not caused by the materials being sucked down in the center of the casting, as often suggested, but are traces of the natural angle of repose of such loose materials. The crystals pile up against the walls of the casting and periodically collapse across it to the center.

Variations in the degree of microsegregation found in different parts of ingots are shown to be caused by convection. E. C. WRIGHT

WESTERN ELECTRIC Sheathes Cable with Metal Jacket on

"Electronic Speedways"



Record-Breaking Soldering Job Accomplished with ALLIS-CHALMERS INDUCTION HEATERS

BEHIND your taken-for-granted telephone is busy *Western Electric* — manufacturing and supplying units of the Bell System. The Allis-Chalmers induction heater is typical of the scientifically engineered machinery utilized by Western Electric in turning out record-breaking quantities of equipment and apparatus essential to dependable service.

In Western Electric's ultra-modern cable sheathing operation, four Allis-Chalmers 50-kw induction heaters at Kearney, N. J., and four identical units at Chicago make up electronic speedways.

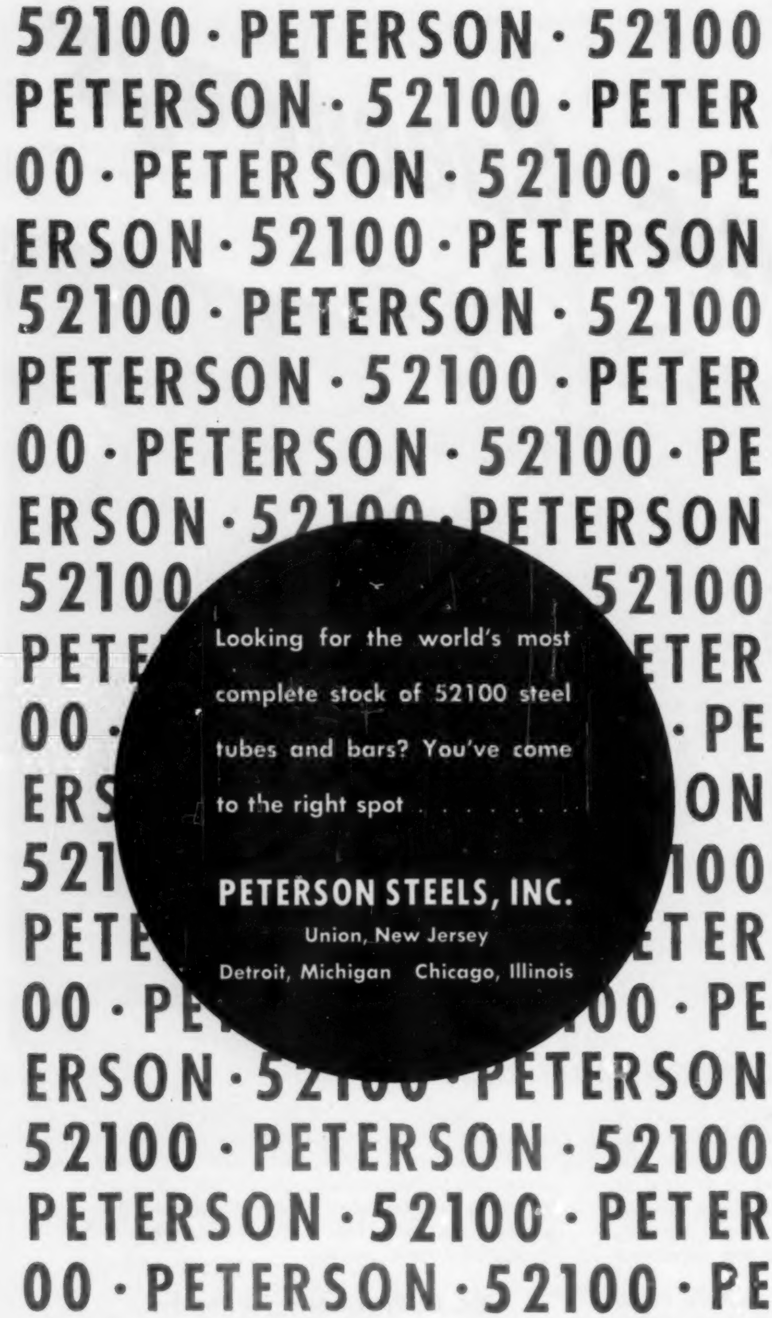
Telephone cables 1¼-inch through 3-inch outside diameter race beneath specially designed induction coils which induce heat into the overlapping areas of the corrugated metal sheathing enclosing the cables. Amount of heat induced depends upon cable speed. Voltage-generating tachometers, magnetic amplifiers and saturable reactors control amount of heat supplied by the coils. Heat is accurately controlled through all speed ranges.

Mr. Hi Frequency is ready and able to help you, too

If your job is one of brazing, soldering, hardening, annealing, or melting, it will pay you to get all the facts on induction heating. Contact your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wis.

ALLIS-CHALMERS

A-5373



Improved Formability . . .

(*Starts on page 82*)

samples had significantly higher notched ultimate strength than the group that was acceptable. Furthermore, the mean ultimate strength of the acceptable group was about equal to that of the previously tested acceptable group, whereas the mean strength of the 40% defective group was somewhat lower than that of the 100% defective group. These results are further proof that the notched ultimate strength is a reliable measure of Lockformer performance.

Study of Production Variables

The high-speed notched tensile test was developed to serve as a means of evaluating variables that affect Lockformer performance in galvanized sheet. Since many variables are involved, much time and effort will be required to investigate them. To illustrate how the test can be used two examples can be given, as follows:

The first production variable evaluated was the amount of top ingot discard. Tests on 40 samples, half with 8% top discard and half with 30% top discard, showed no significant difference in the high-speed notched tensile properties of either the hot strip or the annealed and galvanized sheet. Degree of top discard, apparently, is not an important factor in Lockformer performance, at least in steels similar in composition and production conditions to those tested.

The second production variable involved the notched ultimate strengths of the heads and tails of 20 different coils, sampled at the hot strip mill. The head corresponds to the top of the ingot after 30% top discard, and the tail to the bottom of the ingot. The tail samples had significantly higher strength than the head, which indicates that the tails would have a greater tendency to fail in the Lockformer test. It is possible, however, that this difference is eliminated in subsequent cold reduction and annealing processes. Unfortunately, the heads and tails had lost their identity at the final stage of production so that no similar comparison could be made on the annealed and galvanized sheet.

Annealing . . .

(Starts on p. 111)

Corp.'s Applied Research Laboratory (Monroeville, Pa.) showed that carbon between 0.1 and 0.2%, and manganese between 0.5 and 0.8%, had a minor influence on the strength and ductility of continuously annealed material. Raising the nitrogen, however, from 0.002% to 0.01% increased the hardness on the 30-T Rockwell superficial tester* by 6 points, increased both the tensile and yield strength by 10,000 psi., and lowered the elongation 4%.

Nitrogen not only increases the stiffness of low-carbon steel, but is also largely responsible for strain aging. This type of embrittlement arises when annealed material is given a skin pass of about 1% cold reduction as the final processing step; nitrides then precipitate from the ferrite during storage or service. As pointed out by Eric R. Morgan, assistant director of research for Jones & Laughlin Steel Corp. (Pittsburgh), strain aging is manifested as stretcher strains, buckling, and tearing in deep drawn sheets, and is much more serious than its sister embrittlement quench-aging, which is due largely to carbide precipitation. No known method of controlling strain aging in commercial grades of low-carbon steel is fully satisfactory, largely for economic reasons. As an example, killing the steel with aluminum or titanium will eliminate strain aging but the surface properties are poor and the expense is high.

To end on a note of hope, two possible future procedures in the processing line may reduce strain aging to a tolerable level in rimming steels. One is suggested in the paper by the Russian conferee, M. A. Glinkov, who describes a new type of steel melting furnace whose primary purpose is to knock down carbon, manganese, sulphur and phosphorus to a grand total of 0.05 to 0.07. This "iron" may also be low in nitrogen content. The second procedure is to introduce a favorable residual stress pattern (which masks the yield point) by using higher reductions on the finishing passes and small, roughened rolls for the final skin-pass.

*30-g. load, 1/16-in. ball.

The Forging Industry

Digest of presidential address by C. H. Smith, Jr., to Drop Forging Assoc., 1957 annual meeting.

Mr. Smith noted that past and projected curves of population, gross national product, shell production, and car manufacture indicate an expanding economy in America. Particularly, curves for durable goods manufacture, year by year, parallel shipments of drop forgings, and on this basis a satisfactory growth in his industry might be anticipated. He warned against passive acceptance of this situation, citing three major problems which must be solved by the industry and its individual companies.

First, "one of the most obvious problems is brought about by competition from other methods of producing metal components. Shell molding has opened up new markets for cast products by giving the foundries a technique that makes possible closer tolerances and better surface quality than was hitherto possible by most conventional casting techniques. Investment casting techniques (lost wax and lost mercury primarily) have also created an entirely new industry that we find in competition with the small forging field. In pearlitic malleables we must recognize that modern merchandising and public relations techniques have enabled the malleable founders to improve their positions greatly. Real progress has been made in the past decade with extruded shapes, which compete with forgings in certain areas. The metal stamping industry has made many gains. Weldments and screw-machine products likewise are in the picture.

"To maintain our position in the face of this kind of active competition will necessitate the very best kind of effort in research, manufacturing, merchandising, and public relations. Our first problem, then, as an industry, is to organize ourselves not only to equal but to surpass competitive processes in gaining acceptance for our products.

"A second important problem is one of 'nutcracker' economics. One jaw is the steady climb of steel prices. The other jaw is the strong position of our principal customers. The pattern is quite clear. Every time our major customers are confronted with additional new costs they try to reduce the prices they pay for the things they buy outside.

"Certainly a third major problem we must overcome as an industry is what I call 'technical stagnation'. Stop and think about the operations carried out in your shop today – of the equipment used – of the techniques you now employ. How much improvement can you see in the past five years – in the past ten years – or twenty years?

"A fourth problem confronting us is people. How do we get good people interested in our industry, skilled mechanics, the best possible young men out of our schools? There was a time in American history when the village blacksmith was not only one of the most respected citizens in his community, but also the idol of the younger generation. Today, the average youngster has only one con-

Variety—you can choose from a wide range of finishes for magnesium

Smart, modern furniture is just one example of how finishes for magnesium are widening design horizons. Whether for appearance, protection, or a combination of both, the right finish is available. Magnesium can be painted, chemically treated, electroplated, and coated with plastic or rubber.

To meet the rigorous standards set by the aircraft industry, there are air dried and baked paint finishes with excellent adhesion, maximum imperviousness and good wear resistance. Various types of chemical pickling provide the right paint base. Anodizing provides exceptional corrosion, heat and abrasion resistance. In addition, any metal which can be applied by electroplating may be deposited on magnesium.

What about your products? If you're not making use of magnesium lightness, strength and durability—and the variety of finishes for magnesium—there's no better time to start than right now. Contact your nearest Dow sales office or write to us for more information. THE DOW CHEMICAL COMPANY, Midland, Michigan, Department MA 1405Q.

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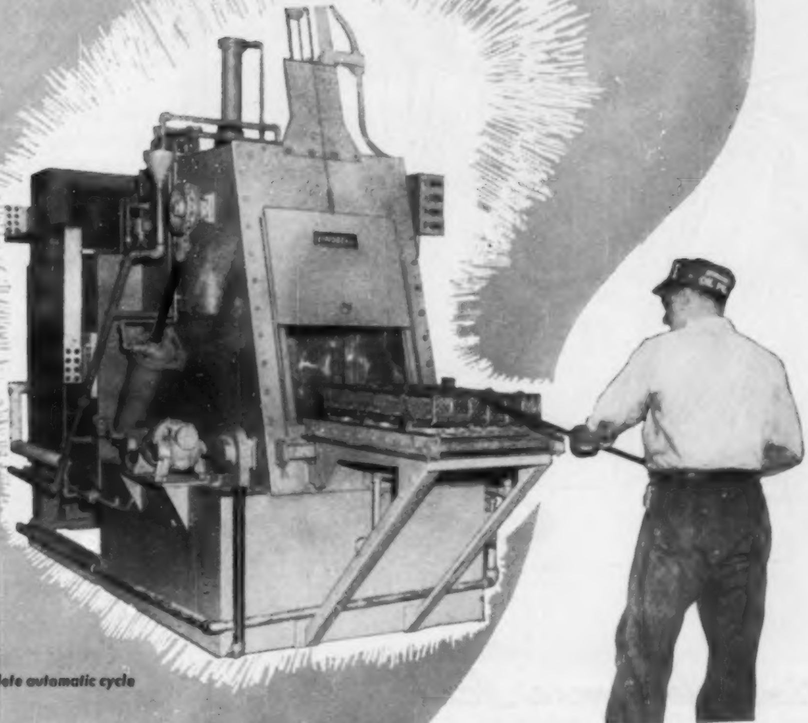
Canadian Distributor — Railway & Power Engineering Corp., Ltd.

Here's the work-horse

for many a carbonitriding job



This furnace has complete automatic cycle and quench control.

This is the most widely-used carbonitriding furnace of all. Day in and day out production of tons and tons of work has proved this furnace's ability to increase production quality and volume and reduce costs. It is a versatile furnace, too, not only for carbonitriding but for other uses, carburizing, annealing, carbon restoration and many hardening applications.

This type of furnace is available for both manual and automatic operation. It can be equipped either with Lindberg's efficient new vertical radiant tubes for fuel-firing or for electric heating with Lindberg's revolutionary new CORRTHERM element.

Versatile as this furnace is, we don't claim it is the best solution to *every* carbonitriding problem. But, whatever your need may be, talk it over with Lindberg. Our engineers, as they have done in so many instances, will recommend a sound answer—design it, build it, even field-install it if you wish. Just get in touch with the Lindberg plant or the Lindberg Field Representative in your locality. Lindberg Engineering Company, 2448 West Hubbard St., Chicago 12, Illinois. Los Angeles Plant: 11937 S. Regentview Ave., at Downey, California.

LINDBERG

heat for industry

Forging Industry . . .

cept of the word 'forged' – he thinks of it as being an illegal way to sign checks, and the average adult thinks a forge shop is a place where a special kind of casting is made."

Mr. Smith recalled that he went to engineering college and took all possible courses in forging. There were only three or four which even mentioned it. The college had a board drop hammer and a helve hammer in the "foundry laboratory" and even these have been scrapped now. In contrast the Foundry Educational Foundation has devoted nearly a million dollars to scholarships in the last decade.

"Still another problem is the obvious financial one. For several years the net earnings of our industry were so poor that we found ourselves in the bottom one-fifth of all key industries in this country.

"Ours are not unsolvable problems. The techniques and methods for curing our ills are now being used widely by wide-awake industries! But, it takes understanding, real work and cooperation."

E.E.T.

Constitution of Mg-Th and Mg-Th-Zr

Digest of "Partial Phase Diagrams of the Systems Mg-Th and Mg-Th-Zr," by A. S. Yamamoto and W. Rostoker, Ⓜ Preprint No. 55, 1957.

Thorium is of considerable interest as an alloying addition in magnesium-base alloys intended for elevated-temperature applications, while zirconium is a very effective grain refiner. The constitution of the Mg-Th system and the effect of zirconium in that connection was investigated because there were only fragmentary and inconsistent data on this important system.

The Mg-Th system was found to consist of a eutectic at 42% thorium and 582° C. (1080° F.) between the terminal magnesium solid solution and a Mg_5Th compound. The eutectic composition was located by intersection of the liquidus temperatures of hypo-eutectic alloys with the eutectic line, and by metallographic examination. The Mg_5Th

Mg-Th Systems . . .

compound in the system forms peritectically at 772° C. (1422° F.) by reaction between melt containing about 53% thorium and an unidentified thorium-rich compound, which may be terminal thorium solid solution. The single-phase Mg_5Th compound could not be produced by annealing treatments, and its composition was determined metallographically by lineal analysis of cast alloys containing lower thorium contents. The structure of the phase was complex cubic with a lattice parameter of 14.2 kX. Its density was estimated as 4.08 from the density of alloys containing lower magnesium contents, from which the number of atoms in the unit cell was estimated to be 120. The solid solubility of thorium in magnesium was estimated to be a maximum of about 4.5% thorium by extrapolation of the solidus and solvus solubility lines, which is somewhat lower than values found by previous investigators. The solid solubility decreases to about 1% of thorium between 300 and 350° C. (570 and 660° F.).

Zirconium was found to reduce the eutectic composition from 42% to 38.7% at 0.64% Zr. The solubility of thorium in magnesium-thorium was found to be about 1%, in agreement with previous work by Leontis of Dow Chemical Co. A Chinese script structure was noted in the as-cast Mg-Th-Zr alloy, which was taken to indicate a ternary invariant reaction between the liquid and zirconium (coprecipitated with magnesium in a eutectic valley reaction) forming magnesium and Mg_5Th, that is, $L + Zr \rightarrow Mg + Mg_5Th$.

The consumption of zirconium in this reaction leads one to wonder what happens to the zirconium; whether it dissolves in the magnesium or in the compound is not stated. Zirconium apparently has little effect on the solid solubility of thorium in magnesium on the basis of metallographic examination of alloys annealed at 550° C. (1020° F.).

ROBERT JAFFEE

Use of Sponge Iron and H-Iron in Electric Furnaces

Digest of "Sponge Iron and H-Iron for Electric Furnace Charging," by P. E. Cavanagh, *Journal of Metals*, December 1956, p. 1642-1644. Based on a paper presented at the Electric Furnace Steel Conference, Chicago, December 1956.

ALTHOUGH electric furnace steel charges in the past have largely consisted of steel scrap, the danger of detrimental tramp elements, now found in purchased scrap, combined with widely fluctuating prices of this material ($40 to $60 per ton) have caused electric furnace melters to seek other sources of iron. Iron ore, pig iron, sponge iron, and lately H-iron are seriously being considered as possible substitutes for steel scrap. Both economic and technical operating factors will determine the outcome.

While high-grade iron ore (over 60% Fe) is a cheap source of iron units, the reduction of iron oxides in an electric furnace presents many difficulties. Large amounts of iron ore in electric furnaces require large carbon charges, high gas evolution and dust problems, greatly increased slag volumes and lively boiling reactions. Electric furnaces are in no way intended to carry out melting under these conditions and melting rates are so slow that melting costs are too high.

Cold pig iron is usually too costly

Sponge Iron . . .

to charge except at integrated steel plants. Hot metal has never been successfully used in large amounts in electric furnaces because it requires either large iron ore charges to oxidize impurities in pig iron or blowing with oxygen. The pig iron ore charge develops the same melting problems as are encountered with large iron ore charges. Some European plants are successfully using oxygen blowing to make electric steel with large hot metal charges in the mix.

The best method of using hot metal is to desiliconize the molten pig iron with oxygen before charging such "wash" metal into the electric furnace. Experiments with this practice have shown that melting rates are almost doubled, and several plants, where hot metal is available, are studying this method.

Sponge iron has been widely used in Scandinavian countries as melting stock in electric steel furnaces. High-grade iron ores are plentiful and cheap while steel scrap is largely imported and quite costly. Over 120,000 metric tons of sponge iron is used annually in electric furnaces. The Swedes estimate the cost of sponge iron at \$30 per net ton as compared to a cost of \$50 to \$55 per net ton in the United States.

Sponge is produced by heating mixtures of carbon and iron ore to temperatures above 2200° F. It usually contains 90% iron with small amounts of carbon and gangue; the purer the ore used, the higher grade of sponge iron produced.

Three types of furnaces are used, namely, the Hoganas tunnel kiln wherein crucibles yielding about 100 lb. of iron are heated in a continuous furnace, the Wiberg-Soderfors shaft furnace using pellets, and the Hojalata y Lamina method at Monterrey, Mexico, where a natural gas-fired tunnel kiln is employed. Hoganas sponge iron is largely used in powder metallurgy while the other types are used as electric furnace charge material. The Swedes have made high-grade steels with 100% sponge iron charges but melting rates are slow compared to steel scrap charges. Several disadvantages of sponge iron charges in electric furnaces are: (*a*) low bulk density, (*b*) low electrical conductivity, (*c*) iron oxide which must be reduced, (*d*) residue ore gangue to be slagged, (*e*) necessity for storing sponge iron in sealed containers to prevent oxidation before melting.

H-iron is a new form of reduced iron developed by Hydro-Carbon Research Corp. Very scanty information is available regarding methods of reduction, cost, and use of H-iron in steel melting charges.

This material is produced in a fluo-solids roast at 900° F. under high pressure and the H-iron powder is compacted by pressing it between rolls and breaking it into chips. Costly equipment is needed to resist hydrogen gas at high pressure and temperature and the cost of reducing gas will largely determine the cost of H-Iron. This process is still in the pilot plant stage. Cavanagh estimates that H-iron will cost about \$45 to \$55 per ton where the cost of natural gas is under \$.50 per thousand cu. ft.

E. C. Wright

Ductile Chromium

Review of "Ductile Chromium, a Review of World Progress on Ductile Chromium", by 49 Authorities. 376 pages, red cloth binding, 220 graphs, charts and tables, 310 literature references. Published August 1957 by American Society for Metals.

ENTIRELY NEW FIELDS of usefulness for chromium and its alloys are forecast by the findings reported by 49 authorities in this new book, "Ductile Chromium". This illustrated volume presents the proceedings of the important 1955 Conference on Ductile Chromium co-sponsored by the Office of Ordnance Research, U. S. Army, and the American Society for Metals.

Here is a factual account of the significant work on the extraction, fabrication and properties of a metal that is a most promising base for new alloys of superior oxidation resistance and strength at elevated temperatures. More than 20 years of intensive research in the United States, Europe and Australia have been devoted to the development of chromium-base alloys for high-temperature service.

Industry has wide use for chromium, with more than a million tons of chromite ore consumed annually in the United States. Since World War II, the Department of Defense has been interested in chromium-base alloys for high-temperature applications and has sponsored many contracts for research and development of such materials.

This book provides the research findings reported by the representatives of such outstanding organizations as Aeronautical Research Laboratories of the Commonwealth of Australia, Battelle Memorial Institute, British Steel Castings Research Association, California Institute of Technology, Electro Metallurgical Co., General Electric Research Laboratory, Horizons, Inc., Massachusetts Institute of Technology, National Bureau of Standards, Office of Naval Research, Rensselaer Polytechnic Institute, U. S. Bureau of Mines, U. S. Department of the Interior, and Watertown Arsenal.

For the man who produces, extracts, tests, fabricates, designs and uses metals, the reports of these 49 experts on chromium contain the most up-to-date and accurate infor-

Tool Steel Topics

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
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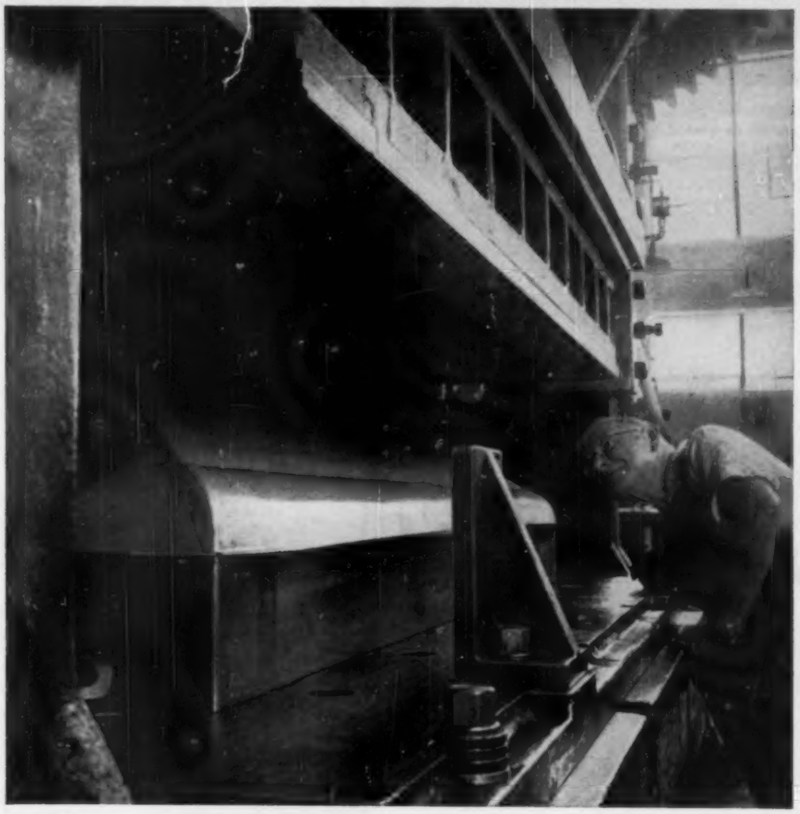

Forming die made from Brake Die steel machines easily, wears longer, cuts costs

It's obviously no job for an ordinary tool steel. The big die made of Bethlehem Brake Die tool steel comes down with a whoo-o-o-m-p, quickly forming the flange for a casket lid, made from 18-gage sheet steel. The action takes place at Boyertown Burial Casket Co., Boyertown, Pa.

"With the die formerly used," said one of Boyertown's engineers recently, "we obtained only average service because of relatively fast wear. Now that we've changed to Brake Die steel, we get much longer wear, and of course greater economy. The grade stands the gaff, and it machines beautifully."

Bethlehem Brake Die saves time in the shop because it comes in the heat-treated condition, ready for machining without further hardening. It has good wear-resistance, a high degree of toughness, and good resistance to impact. After heat-treatment by oil-quenching and tempering, Brake Die is straightened, stress-relief-annealed, then gag straightened. This is your assurance that it is not only straight, but will stay that way when machined to contour.

Brake Die can be used successfully for a wide variety of bending and forming applications. Your Bethlehem tool steel distributor will be pleased to supply full details. You'll find him very helpful, too.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Preheating Tool Steel? Here Are the Facts

Preheating tool steel before heating to the quenching temperature has long been a confusing subject. Some people advocate that every tool be preheated. Others insist it is not necessary to preheat any tools made of certain grades, supposedly because of the "superior built-in quality" of those steels. The truth lies somewhere between these extremes.

Generally, the need for preheating is based more on the size, shape and condition of each individual tool than on the grade of steel from which it is made.

Under the following conditions, preheating is definitely necessary:

1. Large tools should always be preheated regardless of grade, to avoid any possibility of cracking due to thermal stress. Generally, tools whose cross section is 6 in. or more in one direction, or whose length is more than four times the average section, should be considered "large" for this purpose.
2. Tools with drastic section changes (cross section area ratio of 2 to 1, or greater) should be preheated to avoid warping during heating, which otherwise would produce excessively distorted tools after heat-treatment.
3. Where tools are being heat-treated in equipment which does not provide a protective atmosphere, preheating is advantageous. By using a preheat it is possible to hold the heating time in the furnace to a minimum, avoiding excessive scale and decarburization.
4. If tools have been produced by any method of cold working, such as hobbing, shearing, punching, coining, etc., a preheat is necessary to avoid warping or cracking, unless a stress relief operation was used after the cold-work operation.

In addition to preheating under the conditions listed, many heat-treaters use a preheat as a matter of routine, more or less as a form of insurance. For like insurance, preheating also must be considered before troubles arise.

Where a competitive grade of tool steel is used "because it does not require preheating," you can be sure that the equivalent Bethlehem grade of tool steel can also be used successfully without a preheat on tools of the same size and shape.

Ductile Chromium . . .

mation available today. The book's 27 chapters are presented in five sections. Section 1 provides a general review of research on chromium. Section 2 deals with the production of chromium metal. Section 3 discusses ductile chromium metal, with Section 4 devoted to the effect of gas on chromium metal, and Section 5 reports on high-chromium alloys.

This 376-page book includes a 14-page name and subject index and is packed with 220 charts, tables and photomicrographs. Exceedingly helpful are the 310 literature references presented immediately after each of the chapter conclusions.

ERNEST PESSEL

Solubility and Diffusion of Hydrogen in Uranium

Digest of "Hydrogen-Uranium Relationships", by M. W. Mallett and M. J. Trzeciak, ⊕ Preprint No. 36, 1957.

A KNOWLEDGE of the solubilities and rates of diffusion of hydrogen in uranium permits more effective use of this metal, since hydrogen promotes porosity in castings and loss of ductility through precipitation of hydride platelets. In this investigation the authors have studied the solubility and rates of diffusion of hydrogen in massive uranium and the sorption of hydrogen by uranium powder. In addition, hydrogen pressure-temperature relationships in the dissociation of uranium hydride were studied.

Early in the Manhattan Project the solubilities of hydrogen in alpha, beta, gamma, and liquid uranium were reported. A more recent investigation created doubt as to the validity of the original results, but repetition of the original experiments in this work showed that they are valid.

Massive uranium and a hydrogen pressure of 1 atm. were used in the original investigation and the repetition of it, whereas uranium powder and a hydrogen atmosphere of 150μ of mercury were used in the other experiments. Therefore, a series of tests was made on uranium

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Hydrogen in Uranium . . .

powder at pressures between 22 and 324μ and at temperatures between 250 and 500° C. (480 and 930° F.). Solution of hydrogen in uranium is an endothermic reaction, and more hydrogen should dissolve in the metal at the higher temperatures. As the temperature was increased in these tests the amount of hydrogen retained by the uranium powder decreased, which indicated that the main process was not solution. In uranium powder hydrogen is held by sorption, and, as the temperature was increased, the decrease in gases held at the surfaces was greater than the increase in gas in solution. Discrepancies between the solubilities obtained in the two investigations were explained by the differences in the sorption characteristics of solid uranium and uranium powder.

Equilibrium pressures for the isothermal decomposition of uranium hydride were determined to approximately 600° C. (1112° F.). Equations for the determination of the amount of hydrogen soluble in alpha, beta, gamma, and liquid uranium were also made. Solubilities at 1 atm. were calculated, and a phase diagram was constructed.

Hydrogen solubility in uranium increased from 2.2 to 7.8 ppm. in the transformation from alpha to beta; from 9.7 to 14.7 ppm. in the beta to gamma transition; and from 16.9 to 28.1 ppm. in the transformation from gamma to liquid. At 1 atm. hydrogen pressure the hydride, UH_3, formed below 432° C. (810° F.).

Coefficients for the rate of hydrogen diffusion in uranium were obtained by measuring the rate at which solid uranium cylinders were degassed.

R. F. Stoops

Future Potentials for Powder Metallurgy of Titanium

Digest of "Present Limitations and Future Potentials of Powder Metallurgy", by Arthur D. Schwope, paper presented at the Ⓜ Titanium Conference, Los Angeles, March 25-29, 1957.

Much of the original titanium development was done through powder metallurgy methods. Later the process was largely ignored in favor of arc melting which gave promise of yielding a metal with more satisfactory properties. The powder metallurgy process remains interesting in connection with titanium fabrication because of its better material utilization and lower process costs.

One drawback to the use of titanium powder metal parts is the extreme difficulty in obtaining pure titanium powder. Recently the products of both the sodium and magnesium reduction of titanium tetrachloride have yielded fines which are relatively pure. Implications of a fine, pure powder are that the more normal powder processing techniques can be used and that thinner cross sections can be obtained in the pressed article.

Titanium powders are abrasive

(*Continued on p.* 160)

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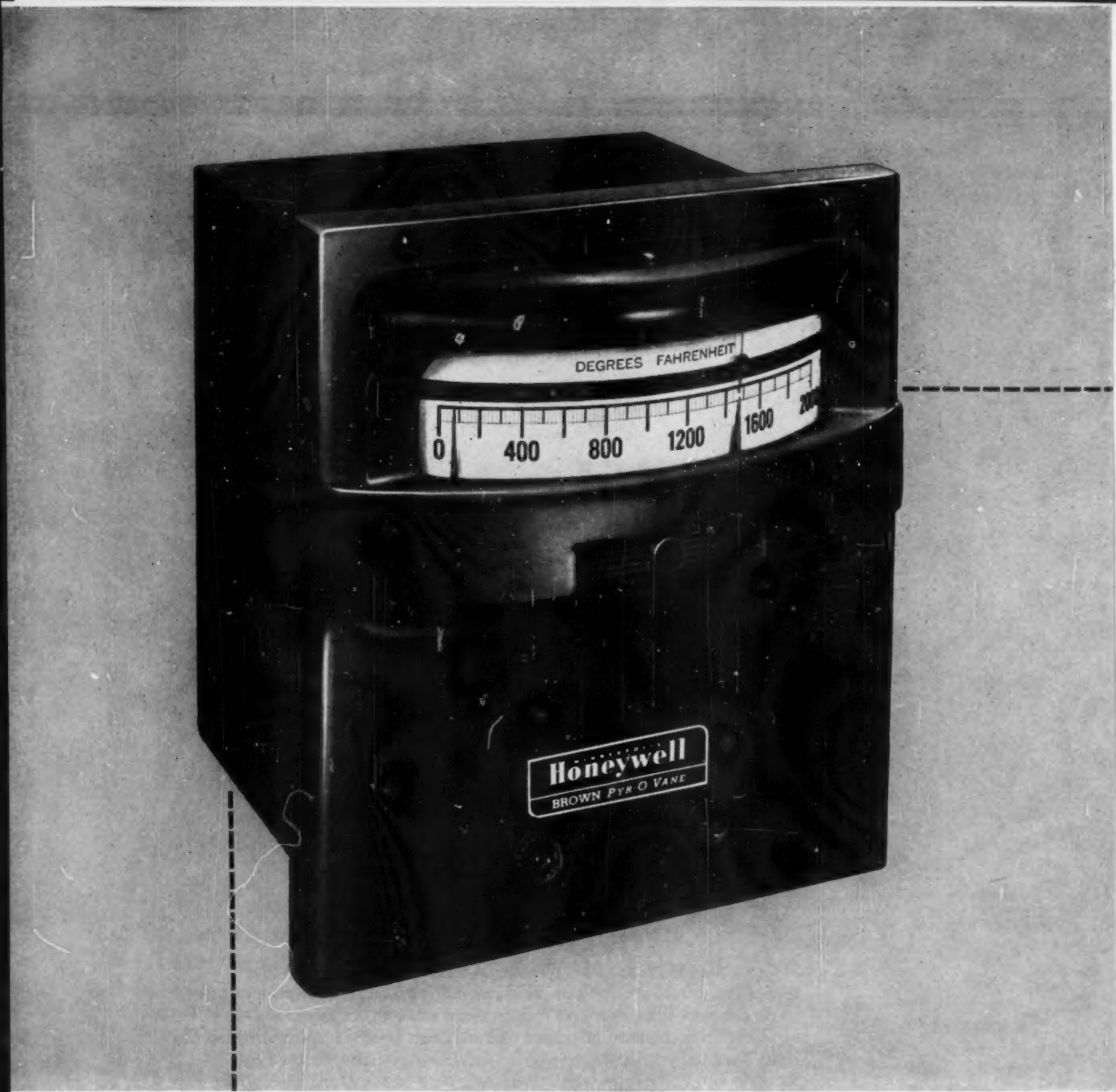

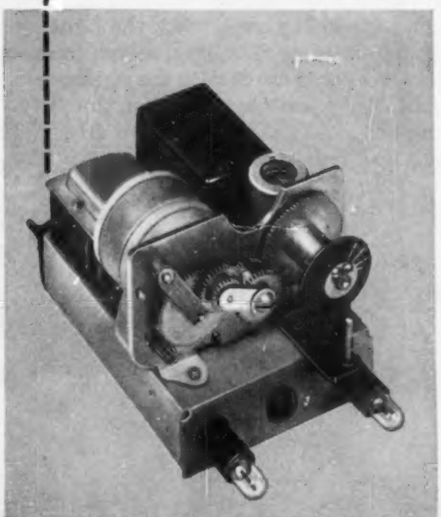

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Titanium . . .

and tend to produce high die wear, but are free flowing with a compressibility ratio between 3 and 4 to 1. Pressing is not difficult and the increase in density with increased compacting pressure is quite marked up to 50 tons per sq. in. Density of compacts pressed with this force range from 85 to 90% of the theoretical. Pressing of titanium powder requires relatively large presses. Pressed parts have good green strength and can be handled freely.

Sintering is done in vacuum furnaces at temperatures in the range of 1500 to 2200° F. Density of titanium increases only slightly during sintering and increases of 1 to 3% are normal for dehydrided powders. Size changes are reproducible and permit good control of part dimensions. Coining and sizing are usually performed, particularly where full density is required.

Mechanical properties of representative titanium alloys range from 60,000 psi. tensile strength and 40,000 psi. yield strength in an unalloyed powder up to 140,000 psi. tensile strength and 130,000 psi. yield strength in a 6% Al, 4% Mn alloy. In general, the mechanical properties obtainable with titanium powders cannot be said to be a limitation to their usefulness. Metal powder parts must be highly densified to attain high strength and this involves higher costs.

Unlike other metals, titanium in powder form is less expensive than it is in primary metal form.

When one considers the high cost of titanium, the high materials utilization factor inherent in the powder metallurgy process becomes important. For example, a part such as a bearing housing for a jet engine can be made with a utilization factor of 1.2 to 1; that is 1.2 lb. of sponge will make 1 lb. of finished parts. It is estimated that if made from solid stock it would require at least 3 lb. of sponge at the outset.

Applications of powder titanium parts are increasing, but new applications must be discovered. Over 90% of today's titanium is going into aircraft where high density and good properties are a prime requirement. Many aircraft designers feel that powder metallurgy is suitable only for low-stressed parts. Many are only beginning to realize that titanium can be fabricated by powder metallurgy to meet high strength requirements. Ignorance of this fact is a major limitation to more widespread applications.

In the proper application of titanium powder metallurgy, one should not merely substitute a powder metal part for one made by a different method. Rather, the whole assembly should be re-engineered to produce greater savings in cost and weight.

Potential applications for titanium powder metallurgy parts exist in the chemical and process industries where corrosion resistance is required and costs of replacement and down-time are important; infiltrated parts of lower density; wear resistant parts such as gears; filters for corrosive liquids; porous parts for transpiration cooling or heating.

T. H. DuMond

Metal Progress

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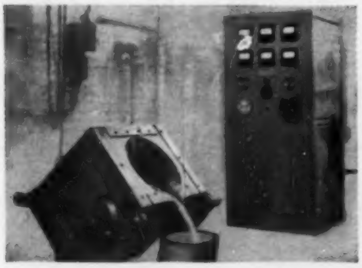

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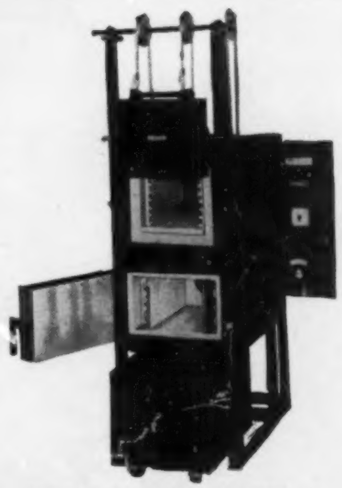

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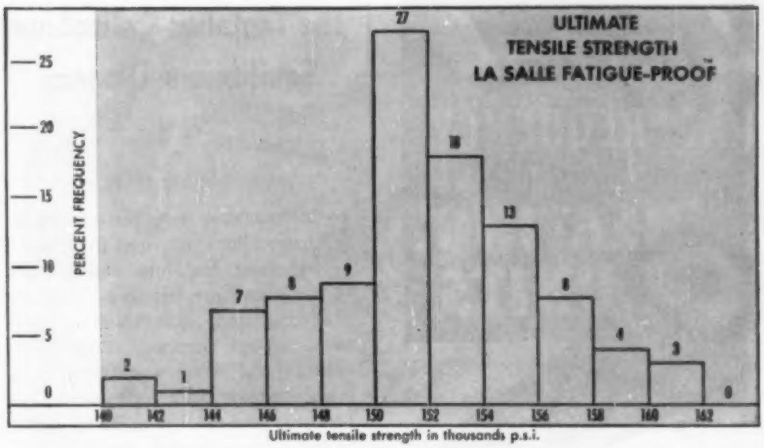

The above chart shows the range of ultimate tensile strength over a period of one year's production. Average value obtained is approximately 150,000 p.s.i.

"e.t.d."™ Process Applied to FATIGUE-PROOF™ Steel Bars Gives Added Strength, Greater Uniformity, Better Machinability

Guaranteed 140,000 p.s.i. minimum tensile... no heat treating necessary

Six important physical and mechanical properties, (1) a high strength level, (2) exceptional uniformity, (3) improved machinability, (4) wear resistance, (5) resistance to fatigue, and (6) dimensional stability, are desirable features of La Salle "FATIGUE-PROOF" steel bars, produced by the new "e.t.d." (Elevated Temperature Drawing) process.

Strength . . . "FATIGUE-PROOF" is a carbon steel bar which replaces both hot-rolled or cold-finished carbon and alloy heat-treatable steel bars. Production figures show hardnesses between Rc 30 and Rc 36 (with a minimum hardness guarantee of Rc 30). The guaranteed minimum tensile strength is 140,000 p.s.i. with a 150,000 p.s.i. average.

"FATIGUE-PROOF" is better than a heat treated bar because it is not quenched and tempered and so the problems frequently associated with quenching and tempering such as (1) quench cracks, (2) non-uniformity of section, (3) soft centers, and (4) heat treat distortion are eliminated. Costly secondary operations such as grinding, cleaning, and straightening are not necessary. Rejects are minimized.

Exceptional uniformity... "FATIGUE-PROOF" is remarkably uniform from bar to bar, end to end, size to size, and lot to lot. Design and production engineers can depend upon it being the same from day to day and job to job.

Individual processing of each bar plus the inherent good qualities and characteristics of the "e.t.d." process account for the excellent uniformity. Microstructures are uniformly pearlitic.

Improved machinability... "FATIGUE-PROOF", made by "e.t.d.", machines 50% to 100% faster than heat treated alloys, and 25% faster than annealed alloy steels. It machines with a very fine finish, and gives excellent tool life. These characteristics make it an ideal steel for production parts.

Wearability . . . Field applications such as gears, pinions, pins, and screws prove that "FATIGUE-PROOF" has good wear resistance. It resists galling and seizure, partly due to its hardness . . . and probably due to the anti-weld characteristics of its chemistry. Further, "FATIGUE-PROOF's" pearlitic structure appears to resist sliding wear better than a quenched and tempered structure of equal hardness.

Resistance to fatigue . . . The chief reason for the failure of highly stressed parts is fatigue. While part shape, unfavorable residual stresses, tool marks, gouges in highly stressed areas, and many other factors contribute to fatigue failure, most materials have also an inherent quality . . . endurance limit that is an indication of ability to resist fatigue.

"FATIGUE-PROOF" has this inherent quality to resist fatigue. Laboratory tests prove that fatigue properties are at least comparable to those of expensive heat treated steels of the same strength level. Numerous field tests, under severe operating conditions, have proved this to the satisfaction of many manufacturers.

Dimensional stability... "FATIGUE-PROOF" maintains a high degree of dimensional stability in machining because of its low order of residual stresses.

Details of the e.t.d." process . . . Elevated Temperature Drawing involves (1) the selection of bar chemistry, (2) the amount of reduction in cross-sectional area of the bar as it is drawn through a special die, and (3) a preselected elevated drawing temperature which will result in the desired final properties.

Although the "e.t.d." process was first announced early in 1957, it has been used in the production of "FATIGUE-PROOF" steel bars since September 1955. Four U.S. Patents (Nos. 2,767,835, -6, -7, and -8) were granted October 23, 1956, covering the "e.t.d." process — an exclusive development of La Salle Steel Company.

How manufacturers can obtain sample Fatigue-Proof steel bars for testing

LaSalle Steel Company has announced that samples of "FATIGUE-PROOF" steel bars, made by the "e.t.d." (Elevated Temperature Drawing) process, are available for test purposes on a no charge basis to manufacturers where it appears that "FATIGUE-PROOF" can help improve products and reduce production costs.

Applications for a sample bar are invited from manufacturers making parts from either hot-rolled or cold-finished carbon or alloy steel bars which require high tensile strength.

Interested manufacturers may write for a test sample by sending a blueprint or application details direct to LaSalle Steel Company, Advertising Department, P. O. Box 6800-A, Chicago 80, Ill.

"FATIGUE-PROOF" is also available from your steel distributor . . . write for his name.

Brochure tells story of Fatigue-Proof steel bars

"A New Material" is the title of a 24-page booklet which gives detailed information covering La Salle "FATIGUE-PROOF" steel bars made by the Elevated Temperature Drawing process.

The booklet presents the results of more than one year's tests of production samples and reports on eight application case studies. Copies available on request.

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The Tantalum-Columbium Equilibrium Diagram

Digest of "The Tantalum-Columbium Alloy System", by D. E. Williams and W. H. Pechin, ⊕ Preprint No. 54, 1957.

INVESTIGATIONS were carried out on binary alloys prepared from high-purity sheet tantalum and columbium. Impurity elements such as iron, titanium, manganese, aluminum, silicon, copper, magnesium, calcium and silver were present in concentrations below 100 ppm. Carbon was present up to 1,000 ppm. in the columbium-rich alloys.

Experimental alloys were melted in a tungsten-electrode arc furnace using a water-cooled copper crucible. The atmosphere was helium, purified by a zirconium getter which was melted in a separate crucible cavity prior to alloy melting. Charges of 70 to 80 g. resulted in button-shaped ingots 1¼ in. diameter by ⅜ in. thick. These ingots were turned over and remelted several times to minimize segregation. Melting losses were seldom as high as 0.1 g. per ingot. Dendritic segregation in some alloys was alleviated by high-temperature annealing at about 2000° C.

The tantalum-columbium equilibrium diagram was investigated by X-ray, electrical resistance and metallographic methods as well as by melting-point determinations. Melting-point bars were annealed at 2000 to 2400° C. (3630 to 4350° F.) for 2 hr., using their own electrical resistance. Temperatures were then raised by this heating method until the melting points were reached. All work was done in a vacuum of 10^{-6} mm. of mercury. The temperature was measured with an optical pyrometer sighted in a small hole drilled in the melting-point bar. The hole was drilled deep enough to insure black-body conditions. The onset of liquid formation in the black-body hole was regarded as the solidus temperature for each alloy. The temperatures at which the bars melted were recorded as liquidus temperatures.

X-ray and electrical resistance measurements were taken to determine the presence of intermediate solid solution transformations as a function of temperature. The X-ray studies were made from powders filed from annealed samples, treated

Ta-Cb Diagram . . .

to remove iron, re-annealed in vacuum for 72 hr. and subsequently cooled to room temperature. Electrical resistance measurements were taken on 0.030-in. diameter wires heated in vacuum. No evidence of an order-disorder transformation was found by either method. Alloys of 25, 50 and 75 at. % tantalum were investigated.

Results showed that the solidus line of the tantalum-columbium constitutional diagram follows a smooth curve from the melting point of columbium to that of tantalum. The temperature difference between the solidus and liquidus was so slight that it could not be detected reliably with an optical pyrometer. Metallographic examinations were made of melting point samples to ascertain that they had been brought to equilibrium by the 2000° C. (3630° F.) anneal. All evidences of dendritic segregation had disappeared after the annealing cycle.

S. T. Ross

Tensile and Creep-Rupture Properties of Chromium

Digest of "The Tensile and Stress-Rupture Properties of Chromium", by J. W. Pugh, ⊕ Preprint No. 44, 1957.

It is possible that chromium-base alloys will become important high-temperature materials. The purpose of this paper is to report the tensile and creep-rupture properties so that some basis for comparing chromium with other refractory alloy bases may be established.

Electrolytic chromium was treated for 20 hr. at 2900° F. in pure dry hydrogen. This treatment was effective in removing sufficient gaseous impurities, notably oxygen, so that a good quality arc-cast ingot might be made. The treated electrolytic chromium flake was fed continuously into a 4-in. diameter water-cooled crucible and melted in a direct current arc. This operation took place in a vacuum-tight shell filled with argon at a positive pressure of 5 psi.

The arc-melted ingot was scalped to 3.5 in. diameter, extruded to 1 in. and scalped and swaged to 0.345 in. diameter. A 1-hr. annealing treatment at 2900° F. in pure hydrogen produced a uniform grain size of about 0.5 mm. Chemical analysis of the bar was as follows:

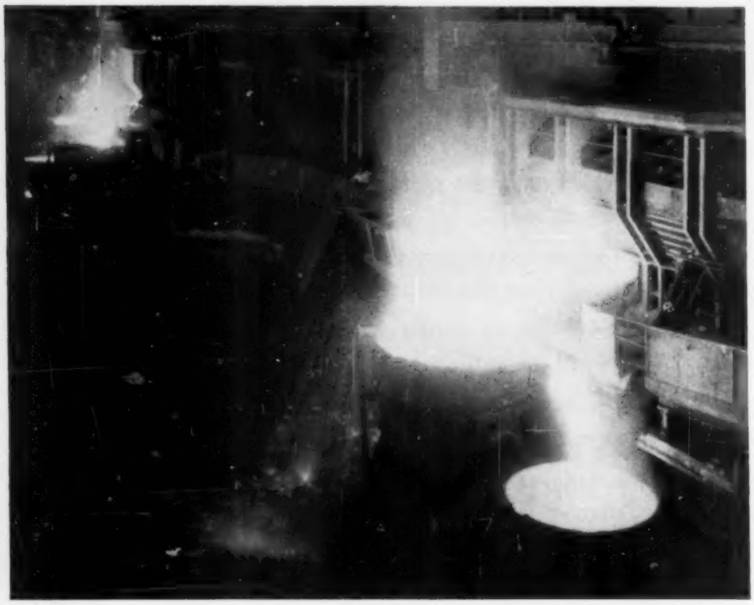
Nitrogen	0.05%*
Oxygen	0.041†
Hydrogen	0.0001†
Carbon	0.01
Sulphur	0.02
Lead	0.001
Iron	0.05
Copper	0.01

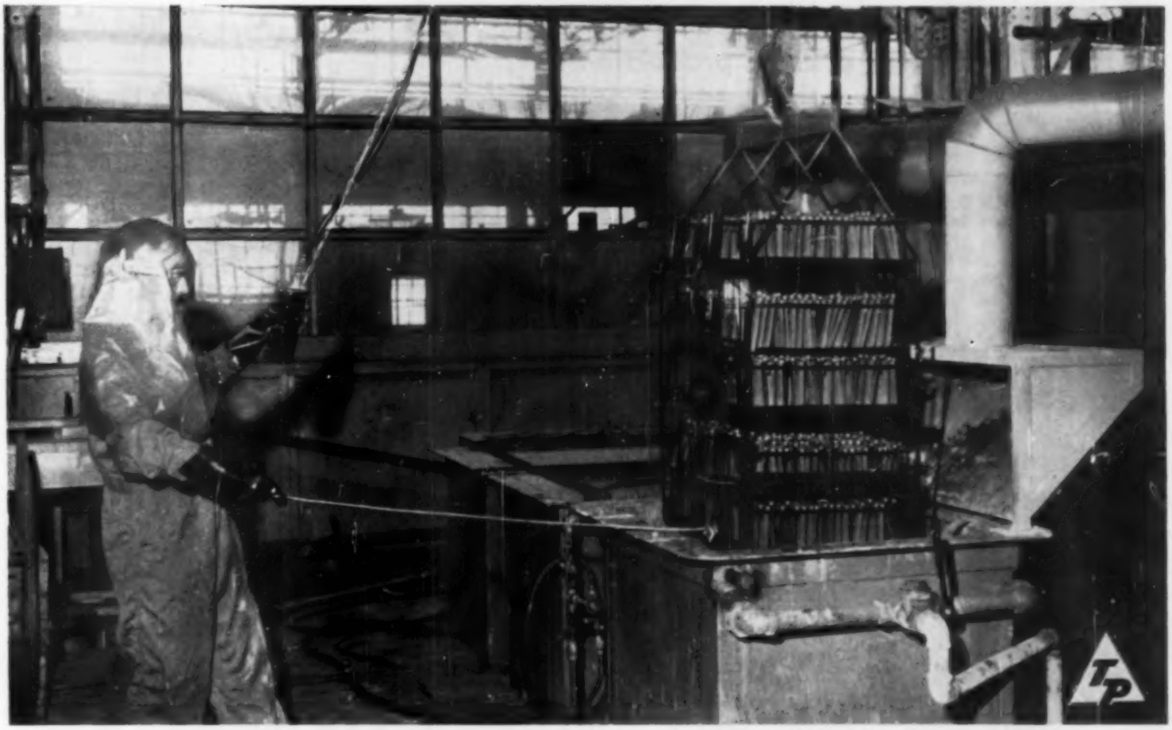
*Kjeldahl.

†Vacuum fusion.

Presumably, oxygen and nitrogen were added in considerable amounts during processing. The expected level of each after the 20-hr. hydrogen purification treatment was about 0.001%.

An evaluation of the hardness response to annealing indicated that increased room-temperature hardness results from treatments in the





How Thompson Products saves $9,750 a month descaling titanium parts in hot Virgo bath

In this plant of Thompson Products, Inc., titanium forgings become mirror-smooth blades for aircraft turbines. But first, workers must get rid of the tough black oxide scale that forms on the parts during forging and heat treating.

They used to *blast* scale loose with a special zirconium sand imported from half-way around the world. But the sand was expensive—$10,000 a month. It had to be purchased and stored 4½ carloads at a time. Stacked in bags, it ate up valuable space—and made a mess when heavy bags burst.

Then this company called in a Hooker sales-service man who showed how they could get the scale off *chemically*. He recommended Virgo Descaling Salt at a cost of only *$250 per month* instead of $10,000 for sand.

Parts come clean in 4 dips

Now titanium parts ride in stainless-steel baskets through four dip tanks—and come out with not a trace of scale. In five minutes in the first tank, molten Virgo salt at 850°F removes almost all of the stubborn scale. In successive dips, cold water removes the adhering molten salt, acid quickly removes the residual soft oxide and hot water rinses the parts clean.

The process descales stainless steel and other high-temperature alloys, too—simply by raising temperature of the salt another 100 degrees. There's no attack on the metal itself at any stage.

It's easier now for inspectors to see tiny defects in the smooth, chemically clean surface of these parts; so quality control is better than before.

Maintenance costs are lower, too: just four dip tanks that need occasional replenishing with salt and acid.

Have you a tough scale problem? Perhaps a talk with a Hooker representative will open a way to substantial cost reductions for you. If you'd like to discover how, just drop us a note on your business letterhead.

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Properties of Cr . . .

range of 1600 to 1800° F. It is suggested that this is caused by increased nitrogen in solution.

Tensile tests were made at the rates of 0.2 and 0.02 in. per in. per min. The specimens were protected from atmospheric contamination by testing in a vacuum capsule. Constant-load stress-rupture tests were made in argon atmosphere at 1400, 1600, 1800, 2000 and 2200° F. The machine used had specimen strings which were enclosed in vacuum-tight capsules.

Yield strength, ultimate tensile strength, per cent elongation, strain hardening, and strain sensitivity were evaluated as a function of temperature. There is a maximum in strength and strain hardening at 800° F. Elongation and rate sensitivity remain low and constant up to about 1000° F. These observations are probably indicative of strain aging in chromium.

By comparison with the higher-melting refractory metals tungsten and molybdenum, chromium is decidedly inferior in strength. The ultimate tensile strength of chromium at 2000° F. is only 40% that of molybdenum and 30% that of tungsten. This suggests that chromium's lower strength may be related to its lower melting point. When ultimate tensile strengths for chromium, molybdenum and tungsten are plotted as a function of homologous temperature, chromium compares favorably.

The temperature dependence of strain rate sensitivity for chromium is comparable to that of tungsten and molybdenum. It is interesting to note that the rate sensitivities of chromium and molybdenum begin rising at the same percentage (38%) of the melting point on the absolute temperature scale.

The same sort of comparison may be made with respect to the temperature dependence of strain hardening. The maximum at 800° F. in this relationship for chromium appears at 33% of the absolute melting point, while similar maxima for molybdenum and tungsten are at 30 and 32%, respectively.

The ductile-to-brittle transition temperature was approximately 600° F. at a strain rate of 0.20 in. per in. per min. Data for tests below 600°

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Properties of Cr . . .

F. are not presented because the stress concentrations in the brittle range make these values unreliable.

Stress values for various rupture times are compared to those for tungsten and molybdenum tested under identical conditions. The superiority of the higher melting refractory metals is striking, but here again a comparison on a homologous temperature basis indicates good correspondence.

A comparison of the tensile and rupture properties of chromium with those of molybdenum and tungsten is an impressive demonstration of the relationship between strength and melting point. More fundamental relationships such as that of the heat content at the melting point undoubtedly exist with the properties evaluated here as they do with hot hardness. It is beyond the scope of this report to demonstrate these. It can be pointed out, however, that chromium has a detriment or an advantage which is reflected by its melting point. On this basis chromium alloys will probably be most useful in a range below that of the higher-melting refractory metals and above that of iron-nickel-cobalt alloys. Specifically, chromium alloys, when they are developed, will probably be useful mainly in the range of 1600 to 1800° F. and for products which utilize chromium's remarkable oxidation resistance.

D. J. Girardi

Oxidation Behavior of a Constantan-Type Copper-Nickel Alloy

Digest of "The Effect of Oxide Recrystallization on the Oxidation Kinetics of a 62:38 Copper-Nickel Alloy", by J. A. Sartell, S. Bendel, T. L. Johnston and C. H. Li, Preprint No. 47, 1957.

This paper describes the oxidation behavior of a 62% copper, 38% nickel alloy in the temperature range of 760 to 927° C. (1400 to 1700° F.). This alloy system is ideal for oxidation studies because of the mutual solubility of the two metals, the greater activity of nickel with respect to oxygen, and the insolubility of the oxides in each other.

Ingots weighing 30 g. were prepared by vacuum melting high-purity copper (99.999%) and high-purity nickel (99.999%) at pressures of less than 10^{-3} mm. Hg. These ingots were rolled to a thickness appropriate for kinetic studies, marker observations and chemical analysis.

For kinetic studies a thermal balance (sensitivity 0.2 mg.) was used. The oxidation furnace was constructed with two zones so that the specimen could be lifted from a cold zone to the hot zone thus minimizing nonisothermal oxidation. Purified dry oxygen was passed continuously through the furnace at atmospheric pressure. Kinetic curves (weight gain versus time) at constant temperatures were plotted.

For marker observations gold-plated platinum wires 0.0025 cm. in diameter were used. Oxidation conditions were similar to those for the

Oxidation Behavior . . .

kinetic studies so that correlation between marker movement and kinetic studies could be made. Accuracy of measurement between markers through a polished cross section normal to the markers was ± 0.00025 cm. Oxidation products were identified by the powder method and counter diffractometer methods of X-ray diffraction.

The oxidation kinetic curves for periods up to 50 hr. (plotted as a square of the weight gain versus time) obeyed two consecutive parabolic laws with the rate constant greater in the second than for the initial period. Because these results differed from those reported by other investigators, argon-melted high-purity and air-melted commercial-purity Cu-Ni alloys also were studied. Their behaviors differed from the vacuum-melted material, indicating that purity of material accounted for the different results.

Microstructure of the oxide surface showed two distinct layers. The outside layer was fine-grained columnar monoclinic CuO. The substrate consisted of a Cu_2O matrix in which NiO particles were dispersed. There were also small isolated particles of NiO in the substrate interface. The presence of CuO rather than Cu_2O as observed by other investigators was attributed to the higher oxygen pressure which was used in this study.

Plots of the square of increase in thickness of respective oxide layers from marker measurements versus time at various temperatures up to 100 hr. showed that the parabolic relationship held true for each layer. However, the outer layer obeyed a single parabolic time law whereas the inner followed two parabolic laws, one for the earlier and another for the later period of oxidation.

Activation energy of 43,000 cal. per mole was calculated for the CuO layer whereas the activation energy for the Cu_2O-NiO layer was initially 44,000 cal. per mole but dropped to 21,000 cal. per mole in the latter part of oxidation.

The following tentative description of the oxidation of the 62-38 alloy was advanced by the authors:

The oxide front moves forward into the alloy by diffusion of oxygen through the Ni-Cu solid solution to nucleate particles of NiO. Growth of the NiO particles continues until the activity of nickel is reduced to zero. Subsequently the copper-rich matrix is oxidized to Cu_2O by diffusion of copper to the oxygen-rich surface. CuO is formed by further oxidation of the Cu_2O and grows by diffusion of Cu^{++} ions to the free oxygen surface.

The continued growth of the NiO front is controlled by the rate of diffusion of oxygen from the Cu_2O-CuO interface through Cu_2O, Cu and CuNi solid solution respectively. The rate at which the anions diffuse through Cu_2O is believed to control the rate at which new particles of NiO are nucleated rather than the chemical diffusion rates of the respective metal atoms. The low rate at which oxygen atoms diffuse through the outer CuO layer does not control the advance of the oxide front because the activity of oxygen in this Cu_2O-CuO

Oxidation Behavior . . .

interface is always high enough to satisfy internal oxidation.

The thickness of the CuO layer is considerably greater than that observed on pure copper. This is attributed to differences in electrochemical potentials at the interfaces which affected the parabolic rate constant.

PAUL G. NELSON

Ductile Cast Iron

Digest of "New Horizons in Ductile Cast Iron", talk by L. J. Greene before the A.S.M. Southern Metal Conference, Jacksonville, Fla., May 1957.

DUCTILE cast iron – ductile as cast – is now melted either in basic-lined cupolas, water-cooled cupolas with no lining or basic electric furnaces. Charges must be arranged to obtain a low-sulphur melt (under 0.03% S).

Much work has also been done on the troublesome problem of introducing the necessary amount of magnesium (0.06%, or 1.2 lb. per ton) to nucleate the graphite particles while cooling in the mold. Past practice has been to add it as a master alloy (Cu-Ni-Mg) containing 8 to 16% Mg. This is rather costly – $15 to $25 per ton of iron to get 42¢ worth of magnesium into it. Alloys of iron, silicon and magnesium have also been widely used and these prevent a build-up of nickel and copper in the iron from recycled scrap.

Much work has been done in Europe to enable the foundryman to add magnesium metal directly to the melt and thus reduce the cost and contaminations which hinder further extension of ductile cast iron uses. Magnesium boils at 2030° F. and can only be added to molten iron at 2800° F. under sufficient pressure to raise the boiling point of magnesium above 2800° F. The Germans have done this by sealing the ladle under sufficient pressure (30 to 50 psi.) and adding the magnesium through a central plunger. Another practice is to seal the ladle tightly and add magnesium which has been coated with a protective refractory. Both of these German methods are patented.

If these technical and economic difficulties can be overcome, Mr.

Ductile Cast Iron . . .

Greene predicts a large increase in applications of ductile cast iron. In comparison with other types of cast iron, he stated that the ductile iron has much easier machinability, 10% less weight for given volume, and can be cast to closer dimensional tolerances.

Experience has shown that ductile iron is a super constructional material for fluid handling equipment such as valves, pipe and pumps. The A.S.M.E. Boiler Code Committee is said to be considering the acceptance of ductile iron up to 1000 lb. pressure as compared to 250 lb. maximum for gray iron.

Numerous automobile and farm equipment parts such as crankshafts, spur gears and drive sprockets are now in production. Mr. Greene stated that one farm equipment builder is erecting a new foundry to produce ductile cast iron exclusively. One important cast iron pipe manufacturer is successfully making large tonnages of pressure pipe of ductile cast iron. It has also shown good heat resistance, due to its greater high-temperature strength and freedom from growth.

E. C. Wright.

Microstructure and Heat Treatment of 16-2 Cr-Ni Steels

Digest of "Effect of Microstructure and Heat Treatment on the Mechanical Properties of AISI Type 431 Stainless Steel", by G. E. Dieter, ⊜ Preprint No. 18, 1957.

Type 431 stainless steel is generally used in one of two heat treated conditions, either a high-hardness condition resulting from tempering at 400 to 800° F. or a low-hardness condition resulting from tempering at 1100° F. or higher. The higher hardness condition gives tensile strength values of 200,000 psi. or better but has been restricted because of its low transverse tensile ductility.

In this paper a study is made of a series of alloys modified in composition to eliminate ferrite which was believed responsible for the poor transverse ductility of type 431 tempered at temperatures of 400 to 800° F. Analyses of these alloys are as follows:

	A	B	C	D
Ferrite	10%	1%	Variable	1%
C	0.15	0.16	0.16%	0.15
Mn	0.88	0.51	0.46	0.68
P	0.014	0.014	0.015	0.017
S	0.012	0.015	0.010	0.013
Si	0.43	0.42	0.49	0.37
Ni	2.12	2.16	2.23	2.17
Cr	16.82	16.22	16.15	15.87
N	0.008	0.011	0.611	0.015

Steels A and D were in the form of 5-in. diameter bars. Steel B was a slab 1½ × 4½ in. Steel C was a 4-in. square forged billet. Steels A and C were reduced 5 to 1 by forging; Steels B and D 12 to 1.

Tensile specimens 0.252 in. in diameter of steel A, austenitized at 1800 and 1900° F. and oil quenched, were tempered at 500, 700, 800, 900 and 1100° F. On specimens austenitized at 1800° F. and tem-

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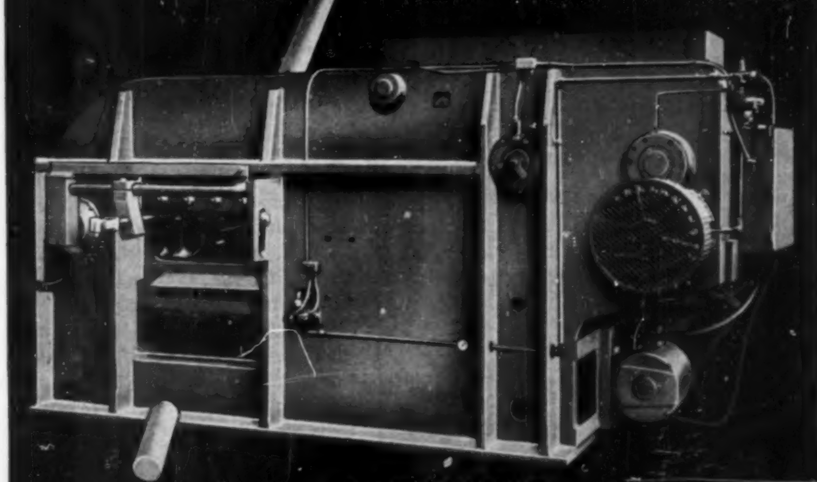

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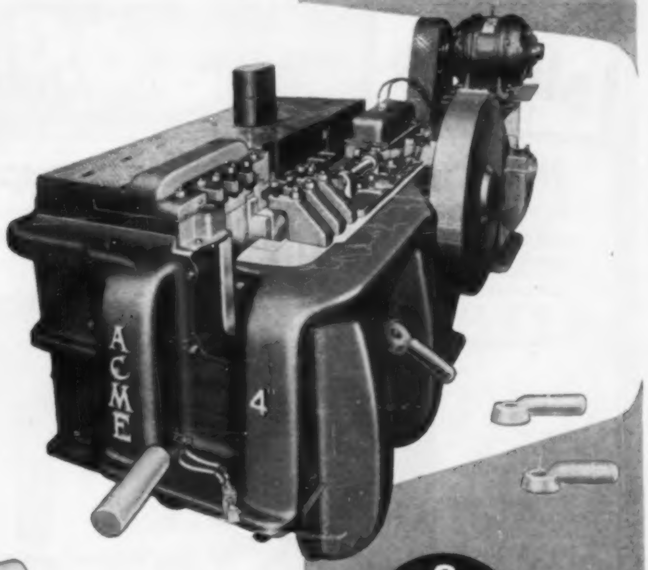

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16-2 Cr-Ni Steels . . .

pered below 1100° F., yield strength (0.2% offset) ranged from 153,000 to 175,000 psi. Ultimate tensile strength ranged from 203,000 to 218,000 psi. Transverse ductility was poor on these specimens with tensile elongation varying from 6 to 11% and reduction in area varying from 2 to 17.5%. On specimens austenitized at 1900° F. tensile strength and yield strength were lower with no appreciable improvement in ductility.

Similar experiments on steel B austenitized at 1900° F., oil quenched and tempered at 500 and 700° F., gave ultimate tensile strengths of 212,000 to 214,000 psi. and yield strengths of 143,000 to 161,000 psi. Transverse ductility was much improved as compared to steel A with elongation values of 15% and reduction in area values of 33 to 41%.

Because these results indicated that presence of ferrite reduced transverse ductility, further tensile specimens were cut from steel C. This steel was segregated with a ferrite-free surface region and a core high in ferrite so specimens were cut from both regions, oil quenched from 1900° F. and tempered at 700° F. The following comparable transverse results were obtained:

	Core (High Ferrite)	Case (Low Ferrite)
Yield	152,000 psi.	153,000 psi.
Tensile	206,000	209,000
Elong. (1 in.)	7%	18%
R.A.	13.1, 14.5	43.5, 48.1%

In an effort to further explain the effects of ferrite, bend tests were made on heat treated sections which had been cut from the segregated area of steel C. Microscopic observation revealed that cracking was initiated in the ferrite.

Because of the high alloy content of steel D, heat treated specimens austenitized at 1900° F., oil quenched and tempered at 700° F. contained about 30% austenite with somewhat reduced yield strength (144,000 psi.). This was increased to 153,000 psi. by a double temper and to 173,500 psi. by refrigerating to −100° F. for 2 hr., followed by a 700° F. temper. With the increase in yield strength, transverse elongation decreased from 16% to 12%. A

lower austenitizing temperature of 1800° F. also increased yield strength but ductility was lowered because of grain-boundary carbide precipitation.

The following conclusions were reached:

1. The transverse ductility of Type 431 at high strength levels is considerably improved when it is free of ferrite stringers.

2. Fracture occurs first in the ferrite stringers and results in stress concentration in the tempered martensite matrix.

3. Transverse ductility is sensitive to the quenching temperature in ferrite-free steel, reaching a low value when grain-boundary carbide precipitation occurs.

4. Retained austenite, which reduces yield strength, can be eliminated by a refrigeration treatment.

PAUL G. NELSON

Nitrided Steel Tools

Digest of "New Horizons in Nitriding," talk by Horace C. Knerr before the A.S.M. Southern Metals Conference, Jacksonville, Fla., May 1957.

THERE HAVE recently been many new applications of nitrided steel parts which extend the use of this heat treatment. Since best nitrided cases are obtained in a long heating cycle (950 to 1050° F. for 45 to 90 hr.), the properties of the metal under the case are greatly affected by this long sojourn at high temperature. The usual nitralloy steels, containing combinations of aluminum, chromium, molybdenum, with or without vanadium, are heat treated prior to nitriding by quenching from 1700° F. and drawing at 1000 to 1100° F. Thus the core hardness and strength are fairly low (Rockwell C-32 hard or 150,000 psi. tensile strength). It results that, although the surface is extremely hard, nitrided tools will not take heavy pressures due to the soft core.

The speaker has found that the use of toolsteels which maintain a hardness above C-60 in the core after nitriding is often very effective in increasing tool life. Most of the common high speed steels have been tried and found greatly superior in such services as cutting tools, punches, drawing dies and cold extrusion dies. He especially recom-

Nitrided Steel . . .

mended a high-chromium-cobalt steel containing 1.50 to 1.70% carbon, 13.50% chromium, 3.3% cobalt, 0.80% molybdenum, 0.50% nickel and 0.20% vanadium. Preferred heat treatment consists of heating to 1850° F. until soluble microconstituents are absorbed in the austenite, and cooling in air or oil; tempering should preferably be done by heating to 900° F. in charcoal or spent carburizer, followed by an oil quench to prevent surface oxidation. After nitriding for 45 to 90 hr. at 950° F., this steel has surface hardness of 1050 to 1150 Vickers Brinell, with a nitride case depth of about 0.025 in. Core hardness will be Rockwell C-62. Greatly increased performance in service has been obtained with these nitrided toolsteels in such operations as dies and mandrels for cold drawing thin-walled tubing in steel, brasses, stainless, and other alloys; for extruding chalk and other powders; dies for swaging, dies for deep drawing shells and cups; dies for stamping and punching.

Mr. Knerr also observed that many heavy sections, such as gears or shafts, could be improved by nitriding Cr-Mo steels of the standard 4140 analysis with considerable savings in costs over using the nitriding alloy. E. C. WRIGHT

Finishing Temperatures for Rolling Steel Plate

Digest of "Effect of Finishing Temperatures on Properties of Hot-Rolled Steel Plate", by R. H. Frazier, F. W. Boulger and C. H. Lorig, *Iron and Steel Engineer*, Vol. 33, October 1956, p. 67-80.

MOST of the rather substantial tonnage of hot rolled steel plate is used in the as-rolled condition; consequently the properties of the plate as it leaves the mill will determine its performance in the numerous applications in which it is used. Since variations in mill practice are known to influence the properties of plate, it is the purpose of this paper to show the influence of one variable, finishing temperature, on the properties of the plate in the hot rolled condition.

This study on the effect of finishing temperature was made on semikilled and killed steels. Rimmed steels were not investigated.

A large number of both laboratory and commercially produced heats were studied. Compositions ranged as follows: carbon 0.15 to 0.25%; manganese 0.50 to 0.75%; silicon 0.05 to 0.10%; phosphorus 0.01 to 0.02%; sulphur 0.02 to 0.04%. The influence of various amounts and combinations of deoxidizers including aluminum, ferromanganese and ferrosilicon was also studied.

From a careful evaluation and correlation of microstructures and mechanical properties over finishing temperatures ranging from 1650 to 2050° F. the following specific conclusions were reached:

1. The resistance of hot rolled steel plate to brittle fracture can be increased by lowering the final rolling temperature. Decreasing the finishing temperature by 100° F. in the range from 2050 to 1650° F. lowered the ductile-brittle transition temperature 6° F. in the Charpy test and 8° F. in the tear test.

2. Lower finishing temperatures produced smaller ferrite grain size. The as-rolled grain size was independent of variations in aluminum content up to 0.04%. After normalizing, however, the aluminum killed steel had a finer ferrite grain size than semikilled steel. Principally for this reason, the beneficial effects of normalizing on toughness were more

(*Continued on p.* 196)

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ELEMENTS OF METALLURGY

Many outstanding authorities have contributed to this popular course edited by Ralph E. Edelman, Chief, Reactive Metals Section, Pitman-Dunn Laboratories, Frankford Arsenal, Philadelphia.

This is a practical course that deals with the behavior of metals in refining, heat treating, fabrication, electroplating and numerous other metalworking operations. It is a course that introduces the student who may have little prior knowledge of chemistry or physics to a down-to-earth study of metallurgy.

Paul R. Brucker, Metallurgist, Crucible Steel Co. of America, Midland, Pa., joins Mr. Edelman in preparation of the first five lessons of "Elements of Metallurgy". *Lesson No. 1* lays the groundwork for an understanding of metallurgy in an examination of the structure of metals, the behavior of atoms and molecules. Following this study of the chemical nature of metals, *Lesson No. 2* concentrates on the physical side and the problems of measurement, expansion, mass and energy, heat transfer and the like.

The chemical changes, or reactions, that take place between elements, between compounds, or between elements and compounds are discussed in *Lesson No. 3*, with *Lesson No. 4* reviewing what happens in any given instance with specific elements in chemical reactions and with the effects of heat and temperature. *Lesson No. 5* points out that the chemical reactions that involve oxides are the foundation for the chemistry of refractories, smelting and combustion, and these are discussed.

Smelting and refractories and metal refining are subjects of *Lessons 6 and 7*, and are prepared by Edward D. Hinkel, Jr., Metallurgist, Carpenter Steel Co., Reading, Pa., with Mr. Edelman. Various smelting processes are described and necessary equipment is illustrated with cut-away charts and pictures. Refining processes that are required to produce a finished alloy from the metal produced by the smelting operations are then presented.

In *Lesson No. 8*, William McNeill, Electrochemist at Frankford Arsenal joins Mr. Edelman in a thorough discussion of electrolytic metallurgical processes, while in *Lesson No. 9*, Harry W. Antes, Metallurgist at Frankford cooperates with Mr. Edelman in an examination of what takes place when refined metals that are poured into ingot molds change from liquid to solid. In *Lesson No. 10*, Leonard Rubin, Research Assistant at Massachusetts Institute of Technology, writes with Mr. Edelman a more detailed discussion of metals structures in this solid state.

Five additional lessons cover heat treatment, precipitation hardening, diffusion and surface treatments, methods of forms and mechanical testing to provide an authoritative study, a practical presentation of a vital area in the metal industry. Mr. Edelman is well qualified to edit this fine course with his experience as Senior Metallurgist, Wright Aeronautical Corporation . . . Staff Metallurgist at Los Alamos Scientific Laboratories . . . Instructor, Metallurgy Extension, Pennsylvania State University . . . prior to his present position with Frankford Arsenal.

HEAT TREATMENT OF STEEL

One of the basic requirements in the processing of steels is their correct and efficient heat treatment. This outstanding, up-to-the-minute steel treating course fills the bill exactly with 15 authoritative lessons prepared by George F. Melloy, Research Engineer, Bethlehem Steel Co., Bethlehem, Pennsylvania.

Scores of pictures, charts and tabular matter are presented by Mr. Melloy in this practical coverage of all important aspects of the Heat Treatment of Steel. You will find this an interesting, helpful study, and a handy, day-by-day reference in the future.

Steel is a versatile material, Mr. Melloy points out in *Lesson No. 1*. He discusses what steel is, what properties make it useful and important, how these properties are measured and evaluated. He covers elasticity, plasticity, tensil testing and other important aspects. *Lesson No. 2* discusses the structure and mechanical properties . . . constitution of steel . . . effect of alloying elements and of heat treatment on mechanical properties.

Lesson No. 3 discusses relationship between structure of steel and its mechanical properties and the two basic methods of controlling structure and hence mechanical properties. *Lesson No. 4* describes annealing of steel—process of heating and cooling to reduce hardness . . . discusses procedures of altering and controlling structure of steel.

Hardening of steel is the subject of *Lesson No. 5*, and Mr. Melloy points out that only in modern times have these principles been understood. Maximum benefits from hardening were not realized until fairly recently. He shows how you can take full advantage of steel with proper hardening processes. *Lesson No. 6* continues a discussion of hardness and the factors involved . . . tests . . . and application of hardenability data.

Factors affecting hardness and hardenability are presented in *Lesson No. 7*, and include effects of carbon . . . alloying . . . quenching and miscellaneous factors. *Lesson No. 8* brings you up-to-date on tempering . . . its three stages . . . effect of temperature and time, of chemical composition and structure . . . of cooling practices.

Surface hardening of steel is discussed in *Lesson No. 9* and includes flame, induction and liquid salt hardening. Heat treatment of cast iron and cast steel described in *Lesson No. 10*, with *Lesson No. 11* discussing protection during heat treatment against decarburization and scaling. Heat treating furnaces, fuels and temperature control are reviewed in *Lesson No. 12*.

Lesson No. 13 outlines the failures and defects to look out for in heat treatment, and *Lesson No. 14* describes grain size—its control and effect. Final *Lesson No. 15* deals with the important area of tools steels—water hardening, shock resisting, nondeforming, hot work and high speed steels.

Mr. Melloy's work on this outstanding course is backed by long years of experience at Bethlehem Steel Company. He is a graduate of Lehigh University with a degree in Metallurgical Engineering, has been an instructor at the Bethlehem Center of the Mineral Industries Extension Services, Pennsylvania State University.

THESE COURSES

". . . Makes my work more interesting . . ." says Student Glen C. Boyce, Chemist and Foreman of the Iowa Malleable Iron Co., Fairfield, Iowa, selected "Elements of Metallurgy" as his M.E.I. study. He writes "I am enjoying this course very much. The fact that the study material parallels my work makes both my work and studies a great deal more interesting."

Executives, engineers, supervisors and production men are taking this in-plant training course on the "Elements of Metallurgy" at Cleveland Pneumatic Tool Co., Cleveland. Dr. Anton deSales Brasunas, Director of Metals Engineering Institute is teaching this class of 22 students. Training Directors and employers have shown great interest in these metals training courses for management, engineering, production and sales executives.

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The quality and authority of this course is the natural result of its learned preparation by Dr. Clark, who is a graduate of the University of Michigan with BSE, MSE and PhD degrees. After lecturing in Metallurgical Engineering at the University, he joined the Steel and Tube Division of the Timken Roller Bearing Company, where he is now Metallurgical Engineer, Special Steel Developments. He has developed a number of alloys, holds several patents, has published 100 papers. He is active in many societies and on many technical committees, has received a citation from his University as a distinguished alumnus.

TITANIUM

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R. L. Powell, Supervisor, Process Research Division, Titanium Metals Corporation of America, Henderson, Nevada, prepared *Lesson No. 2* on the extractive metallurgy of titanium. He discusses production from titanium dioxide, from titanium tetrachloride . . . describes purification, chemical reduction, electrolytic reduction.

Lesson No. 3, by Dr. Finlay, surveys titanium-base alloys . . . gives the ABC's of titanium alloys . . . their structure, heat treatment, etc. In *Lesson No. 4*, Dr. Robert I. Jaffee, Chief, Nonferrous Physical Metallurgy Division, Battelle Memorial Institute, discusses physical metallurgy . . . describes important alloying elements and major contaminants. Dr. Jaffee continues in *Lesson No. 5* with a discussion of beta transformation, heat treatment and thermal stability.

Physical and mechanical properties of titanium are presented in *Lesson No. 6* by D. R. Luster, Chief Supervisor, Research Department, Rem-Cru Titanium, Inc. This lesson reviews what is now known of these important properties and indicates the probable properties that can be expected from yet-to-be developed alloys.

Mr. Luster discusses the metallurgy of titanium in *Lesson No. 7*, and in *Lesson No. 8*, Dr. Finlay describes melting, casting and the powder metallurgy of titanium. Mill processing is covered in *Lesson No. 9* by two experts . . . Dr. Lee S. Busch, Director of Research and Richard J. McClintick, both of Mallory-Sharon Titanium Corporation, Niles, Ohio.

Machining and grinding of titanium is detailed in *Lesson No. 10* by John P. Catlin, of Rem-Cru Titanium, Inc., and in *Lesson No. 11*, George C. Kiefer, of Allegheny Ludlum Steel Corporation, Brackenridge, Pa., discusses corrosion resistance, surface conditioning and chemical analysis.

Final four lessons give outstanding coverage of joining operations, by Glen E. Faulkner, Research Engineer, Battelle Memorial Institute . . . airframe designs, manufacture and uses, by Gordon A. Fairbairn, Supervisor, Materials and Processes, North American Aviation, Inc., Los Angeles . . . titanium jet engine design, by M. E. Cieslicki, Supervisor, Materials Control, General Electric Company, Cincinnati . . . latest developments and trends, by W. Stuart Lyman and E. W. Cawthorne of Titanium Metals Laboratory.

Here is a study course written by outstanding experts, edited by a recognized authority, Dr. Finlay, a graduate of Lehigh University, with a Master's Degree and a Doctor's Degree in Metallurgical Engineering from Yale University, Prior to his association with Rem-Cru, Dr. Finlay was Supervisor of Chemical and Metallurgical Research for Remington Arms Company.

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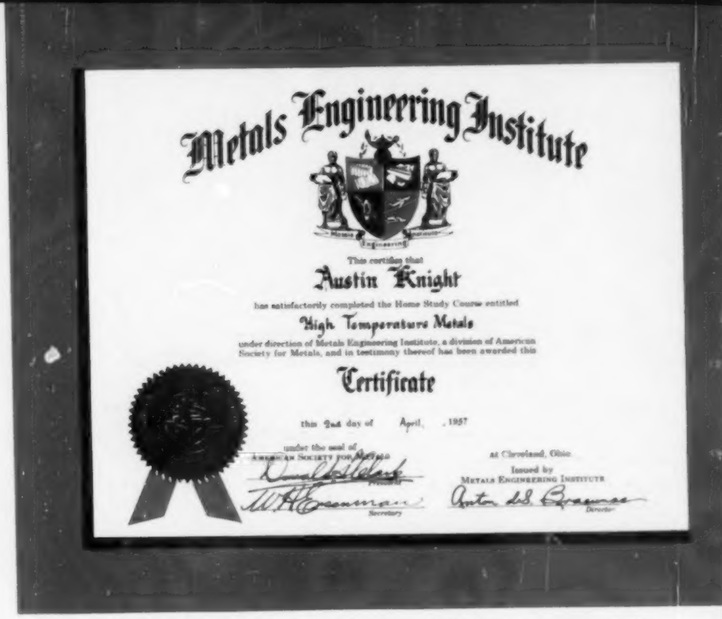
Anton deS. Brasunas

Anton deSales Brasunas, Director
METALS ENGINEERING INSTITUTE

Dr. Anton deSales Brasunas was appointed Director of the Metals Engineering Institute after a long search for just the right man who, by education and experience, would most ideally qualify for this important post. Dr. Brasunas came to MEI from the University of Tennessee where he was associate professor of metallurgical engineering. Prior to that time, he was associated with the Oak Ridge National Laboratory and with Battelle Memorial Institute. He is a graduate of Antioch College, received his MSc. degree from Ohio State University, his Sc.D degree from Massachusetts Institute of Technology.



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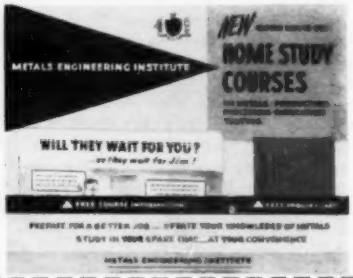

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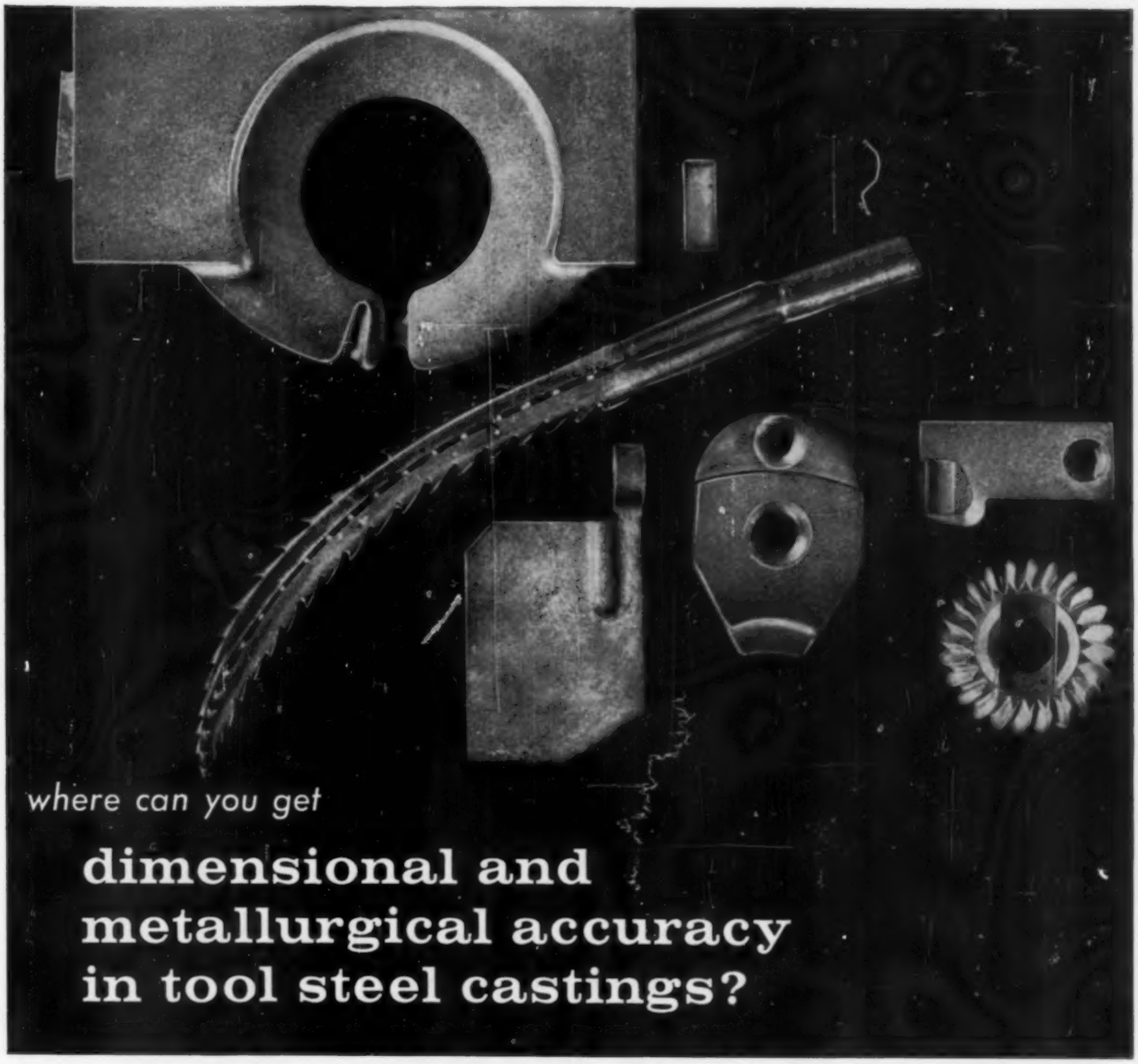

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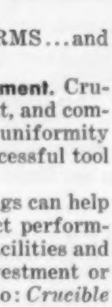

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3. Within the range investigated, lower finishing temperature raised the yield strength of hot rolled steel plate. Finishing temperature had no effect on ultimate strength or elongation values. W. W. Austin

Corrosion by Liquid Metal

Digest of "Problems in Reactor Coolants", talk by E. E. Hoffman before the A.S.M. Southern Metals Conference, Jacksonville, Fla., May 1957.

This discussion was confined to circulating systems wherein molten metals or metallic alloys, such as sodium, sodium-potassium eutectic ("Nak"), lithium, lead and lead-bismuth alloys are used as heat transfer mediums between power reactor elements at temperatures up to 1800° F. and steam generators at 700 to 1000° F. All containers, tubing, pumps, drums, and valves must withstand the high temperatures encountered, resist chemical attack by the fluids present, and the insidious "mass transfer" effect which develops in these systems.

In preliminary studies at Oak Ridge National Laboratory, extensive static and dynamic corrosion tests have been made on many variations of container metal and fluid transfer alloy. Isothermal static tests are fairly simple to conduct. A simple container of heat resistant metal is loaded with a certain fusible alloy, kept at the desired test temperature for the desired time, and the weight loss of container and weight gain of the liquid determined. One necessary precaution is that all loading must be done in an inert atmosphere since impurities in the fluid metal accelerate corrosion. Attack suffered by the containers in dynamic systems, where a large temperature difference exists between hot and cold sections, is much greater. Such work is usually done in a "loop" made of the container under investigation – say, Inconel. A small boiler is half filled with the fusible metal – say sodium – and for this liquid the boiler is heated to 1490° F. Sodium vapor is liquefied

Corrosion . . .

in a condenser leg and passes along through Inconel tubing in which are two low spots or sogs which act as hold-up traps. The liquid sodium finally drips into a receiver at 790° F. so arranged that it can be sampled, and from which the sodium re-enters the boiler by the return leg of the loop.

Studies of such systems indicate that there are no less than six mechanisms of corrosion by liquid metal:

1. Simple solution.
2. Alloying between liquid metal and solid metal.
3. Intergranular penetration of the containing system due to selective removal.
4. Reactions with impurities.
5. Mass transfer due to temperature gradient.
6. Mass transfer or dissimilar-metal transfer, due to concentration gradient.

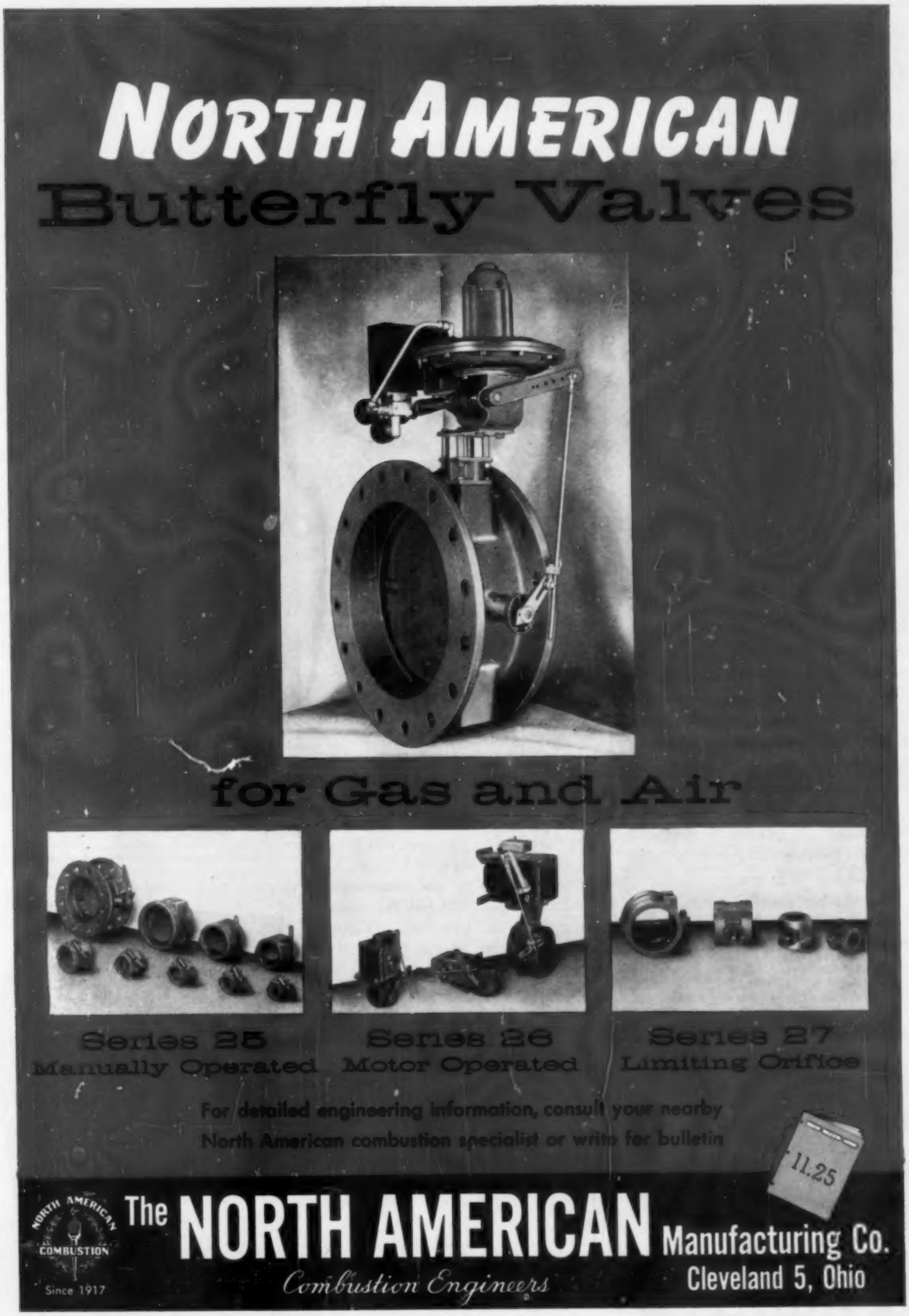
The last two conditions cause great difficulty. Mass transfer due to temperature gradients results from alloying of the liquid metal with container metal in the hot leg and the freezing out of such alloys in the cold leg of the system. Mass transfer by concentration gradient results from the selective alloying of the liquid metal at a junction of two dissimilar metals in the container assembly. Where adequate phase diagrams are available, the latter effects may be fairly well predicted.

Mr. Hoffman gave some data for systems of various metals containing lithium, in the form of a bar chart showing temperatures for which dynamic systems could be operated for 1000 hr. – really a very short time, 41 days – with less than 0.005 in. of attack on the container. This puts iron high in the list:

Refractory metals	1500° F.
Iron	1200
Stainless steels	1100
High-nickel alloys	800
Low-alloy steels	600
Nickel	550

These figures for the various containers of liquid helium are indicative of the great difficulty of maintaining fluid metal transfer systems in a large power reactor.

E. C. Wright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Electroplating Titanium

Digest of "Protective Coatings for Titanium", *Technical News Bulletin*, National Bureau of Standards, Vol. 40, December 1956, p. 174-175.

GREATER ADVANTAGE could be taken of the high strength-to-weight ratio of titanium if it could be coated effectively with a metal not subject to galling or high-temperature oxidation. An oxide film on titanium has always prevented the adherence of any metal coating applied electrolytically by ordinary methods. However, when a titanium specimen cleaned by abrasion inside an evacuated glass tube was immersed in a chromium-plating bath and the tube then broken in order to expose the specimen to electrochemical action, a distinctly improved adhesion of the chromium plate was attained.

A method more convenient in practice is to form a fluoride coating on the titanium by suspending clean dry specimens in a solution of hydrofluoric and acetic acids. After 10 or 15 min., a 60-cycle alternating current is passed through for another 10 min. These specimens have a coating of a low-valence titanium fluoride containing 37% Ti, and can be plated effectively in a conventional chromium plating bath at 185° F. and a current density of 120 amp. per sq. dm.

The bond strength of a chromium plate applied in this way was tested by electrodepositing a 1/16-in. cobalt nodule on it, and determining the force required to pull the nodule away from the titanium. Fracture always occurred in the plate. The bond was improved by heating the plated specimen 2 min. at 1470° F. Strengths of 4000 to 18,000 psi. were obtained in this way.

Coatings of 0.02 mm. chromium plus 0.15 mm. nickel on titanium were moderately adherent without heat treatment, but not comparable to that of chromium on steel. The coatings on such specimens ⅜ in. wide, broken by repeated bending, could be stripped from the titanium with a force of about 10 lb.

Copper and nickel deposited on titanium by a similar method have often blistered, and do not adhere as well as chromium.

GEORGE F. COMSTOCK

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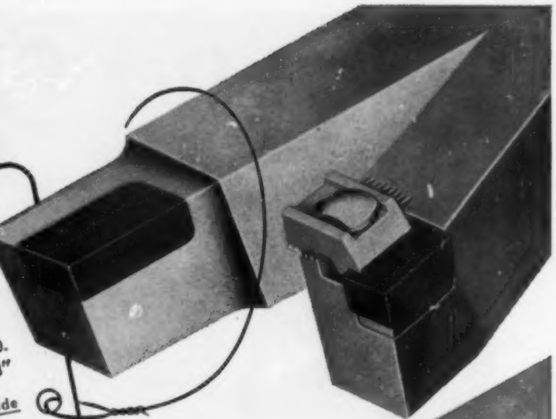

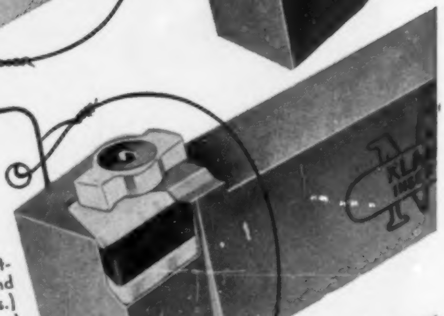

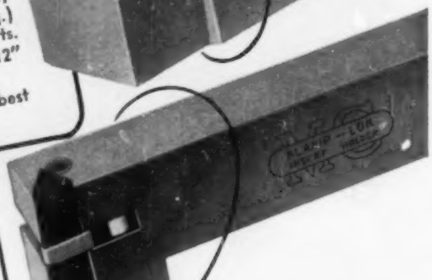

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Tool...........Standard Talide tool AL-10-5/8" sq. x 4", Grade S-90.
Speed (S.F.M.)....400 Feed.....005" Depth of Cut.....003"

	Talide Grade S-90	Next Best Premium Grade
Average No. of pcs. per grind	600	475
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90 DAYS OF GRUELING TESTS at eastern aircraft engine plant rates Talide Grade S-92 "Best by Test."

Here is one typical result:
Machine........36" Bullard Multimatic
Material........AMS-5613 Stainless Steel
Operation......Facing, turning and boring 21" O.D. x 2.5" thick casting to size. (Heavy scale, bead weld, and out of round surfaces presented adverse machining conditions.)
Tools...........TN-163P3 (1/2" I.C.) and SN-243P3 (3/4" sq.) Talide "Throw-away" triangular and square inserts.
Speed (S.F.M.).......375 to 1100 Feed...........006" to .012"
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Result..........27-34 Pc. average compared to 7-12 for next best premium grade—plus tool breakage cut 75%.

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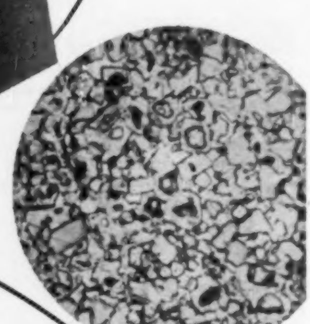
Cutting Tool.........................Style TB-12123 Triangular Insert

Material	Talide Grade S-90	2nd Best Carbide	3rd Best Carbide
1141 Steel	175 pcs.	120 pcs.	97 pcs.
4140 Steel	128 pcs.	70 pcs.	65 pcs.
Armor Steel	83 pcs.	65 pcs.	65 pcs.



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ARMASTEEL 88M does not require heat treating and thus relieves customer facilities or eliminates capital expenditures. In many parts, distortion is a problem after heat treating. Parts made from ArmaSteel 88M can be machined without further heat treatment and still give good wear resistance.

This new castable metal is a pearlitic malleable iron which possesses substantially the same strength and the same wear characteristics as alloy steel forgings. Being a castable material, it has the two advantages of design flexibility and good machinability. Why 88M possesses these characteristics—and how it will fill the needs of American industry will be of interest to manufacturers and engineers in many fields . . .

PRODUCTION OF 88M—By accurately controlling the heat-treatment of ArmaSteel 88M in controlled atmosphere furnaces at 1750° for approximately 15 hours, all massive carbides are removed. This heat treatment is followed by a rapid air quench from high velocity fans. Tempering is controlled to provide a narrow range of hardness.

Automatic Transmission Planet Gear Carrier

Universal Joint Yoke

Surface hardening of ArmaSteel, if desired, does not require carburizing. Instead, flame-hardening, induction-hardening or simple immersion methods may be used. A surface hardness of 50 Rockwell C to 60 Rockwell C can be readily obtained. Wear-resistant properties in the hardened area are comparable and sometimes better than carburized steel, while the remaining sections retain their original toughness.

MACHINABILITY—In addition to performance characteristics, ArmaSteel offers good machinability. Carbon spots that are present in the Matrix of ArmaSteel allow the chips to break off readily, effectively reducing machining time and prolonging tool life. In comparative tests, ArmaSteel shows itself to be a more freely-machining material than steel bar stock or forgings of the same Brinell hardness.

Because of its ability to assume the shape of practically any molded cavity, 88M not only permits great

PEARLITIC MALLEABLE IRON?

88 M *developed by*

CENTRAL FOUNDRY DIVISION

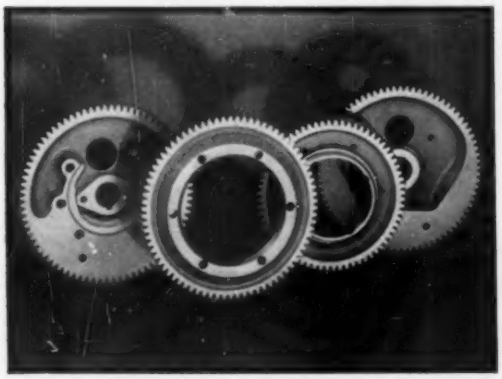
Transmission Output Shaft

freedom in design but also possesses certain inherent physical characteristics not present in forgeable alloys.

APPLICATIONS—ArmaSteel 88M is now being cast for automatic transmission planet gear carriers and universal joint yokes for leading automobile manufactures. Other interesting applications now in the testing stage include transmission output shafts, and diesel engine idler, balance and crankshaft gears.

Just what hundreds of other applications are in store for 88M is still anyone's guess. But the more one examines its characteristics, the more it would seem that it will fill many needs in many types of products and industries. In your products, for example, you may well see where 88M could both improve performance of components subject to great wear or great stress, and at the same time reduce final cost because of the economy in casting and the economy in a material with superior machining characteristics.

Diesel Engine Idler, Balance and Crankshaft Gears



CASTING—Parts are cast in ArmaSteel 88M, here at Central Foundry Division, in either standard green-sand molds or the newer, more precise shell-molds. In addition to 88M, Central Foundry Division produces castings, on a volume basis, in grey iron, alloy grey iron, malleable iron, and ARMASTEEL 84M, 85M and 86M.

Our research facilities and engineering staff are prepared to help you determine whether 88M or any of the other materials now being cast at Central Foundry will fill your needs or help you reduce your over-all product cost.

Write for your copies of our two comprehensive manuals, "ARMASTEEL" and "SHELL CASTINGS."

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GENERAL MOTORS CORPORATION • SAGINAW, MICHIGAN • DEPT. 19

MOLY NEWS

CLIMAX MOLYBDENUM COMPANY, 500 FIFTH AVENUE, NEW YORK 36, N. Y.

Ultra-Strength Steels Boost Tensile Strengths to 300,000 psi.

Ten years ago, engineers considered 180,000-psi tensile strength in steels the maximum they could use safely.

Today, alloy steels with minimum strengths of 220,000 to 300,000 psi are being used commercially. These ultra-strength steels have the ductility and toughness needed for structural applications. At tensile strengths above 220,000 psi, they show more strength per pound of product than high-strength aluminum alloys. And at 260,000 psi, they are approximately 15% lighter than aluminum alloy products of the same strength.

Molybdenum is an essential element in almost all of these steels.

How are the higher strengths and strength/weight ratios of these steels being used? Until recently, they've been utilized almost exclusively in aircraft components, such as landing gear. Now, however, they're being considered wherever weight and space savings compensate for higher fabrication costs . . . as, for example, in equipment that must be moved (portable tools); gears, pulleys, belts, liners; heavy machinery operating at high stresses; machinery where inertia is a design factor; materials-handling equipment, such as cranes; and transportation equipment.

Like to know more about ultra-strength steels and their properties, and the names of manufacturers? For our free booklet, circle #1 on the coupon.

Bulletin Shows How to Get Heat Resistance in Cast Iron

In cast iron, heat resistance can mean different things: resistance to growth, to heat checking, to scaling, or to deformation under load at high temperatures.

"Why Moly Iron? #5" contains a chart showing the specific kinds of heat resistance needed by parts such as brake drums, melting pots, piston rings and so on. This chart also lists the best type of iron to use and the proper alloy additions. A number of detailed case histories document this useful bulletin.

For a free copy of "Why Moly Iron? #5" circle #2.

New Coatings May Solve Moly's Oxidation Problem

The most important obstacle to using molybdenum at high temperatures is being overcome. Oxidation is the problem; at temperatures over 1000F, molybdenum oxidizes rapidly.

Newly developed coatings offer molybdenum the needed protection. Three types are promising:

1. Electro-deposited chromium and nickel layers which protect molybdenum to 2000F.

2. Sprayed coatings of aluminum-chromium-silicon alloys, and nickel-boron alloys, which have proved effective at 2000-2400F.

3. Ceramic and molybdenum disilicide coatings which hold promise of protecting molybdenum from oxidation at even higher temperatures.

Digested from "Protecting Molybdenum at High Temperatures" by Julius Harwood, Materials & Methods. For reprint of entire article, circle #3.

Booklet Deals with Molybdenum Joining Techniques

Recent progress in joining molybdenum, and suitable means for protecting it from oxidation, are opening up new uses for molybdenum and its alloys in structural components for high-temperature service.

"A New Look at Joining Molybdenum" by R. R. Freeman and J. Z. Briggs, both of Climax, analyzes the factors involved in joining moly and discusses the methods available.

For the free booklet, circle #4.

List of Moly Literature Now Available

Copies of more than 30 recent pieces of technical literature on molybdenum are available from Climax Molybdenum Company. *For a free list of these, including titles, authors, sources and 25-30 word summaries, just circle #5.*

Steels for Power-Plant, Refinery Equipment at 900-1100F

Designers of power-plant and refinery equipment who need to select steels for applications at 900 to 1100F will be interested in a copy of "Chromium-Molybdenum and Chromium-Molybdenum Vanadium Steels for power-plant and refinery service up to 1100F."

This paper, presented at the ASME annual meeting by George V. Smith, Bard Professor, Cornell University, appraises literature on the subject and draws some new, objective conclusions.

For a free reprint, circle #6.

New Climax Alloy Proves Unusually Wear Resistant

These liner castings, made of Climax 321, proved highly resistant to wear in our ball mill discharge launders. Severe wear normally occurs in this operation as a result of erosion from the coarse pulp flowing out of the ball mill discharge.

If you need a highly wear-resistant material, you may be interested in our new Climax 321 Alloy. It's a hard, martensitic type of white iron containing nickel, chromium and molybdenum in proportions that are well balanced, both metallurgically and economically.

We've been using 321 Alloy in our own mining operations with exceptional results. Comparative tests in ball mill liners and grinding balls proved its excellent wear-resisting properties.

Because this alloy is relatively new, service results in other applications are not yet available. However, our laboratory studies and data indicate it should prove suitable for the general run of abrasion-resistant castings of the martensitic white iron type—such as wear shoes, sand and dredge pump wearing parts, pug mill knives, mixer liners, etc.

Climax 321 can be melted in a cupola or electric furnace and cast in either sand or permanent (chill) molds. It has a normal hardness range of 55 to 62 Rockwell "C".

Composition: Carbon 3.30-3.60%; Silicon 0.30-0.60; Manganese 0.50-0.80; Nickel 2.75-3.25; Chromium 1.75-2.25; Molybdenum 0.70-1.10; Sulphur 0.15 max.; Phosphorus 0.30 max. *For data sheet, circle #7.*

Climax Molybdenum Company, Dept. 5
500 Fifth Avenue, New York 36, N. Y.

I'd like more information on:

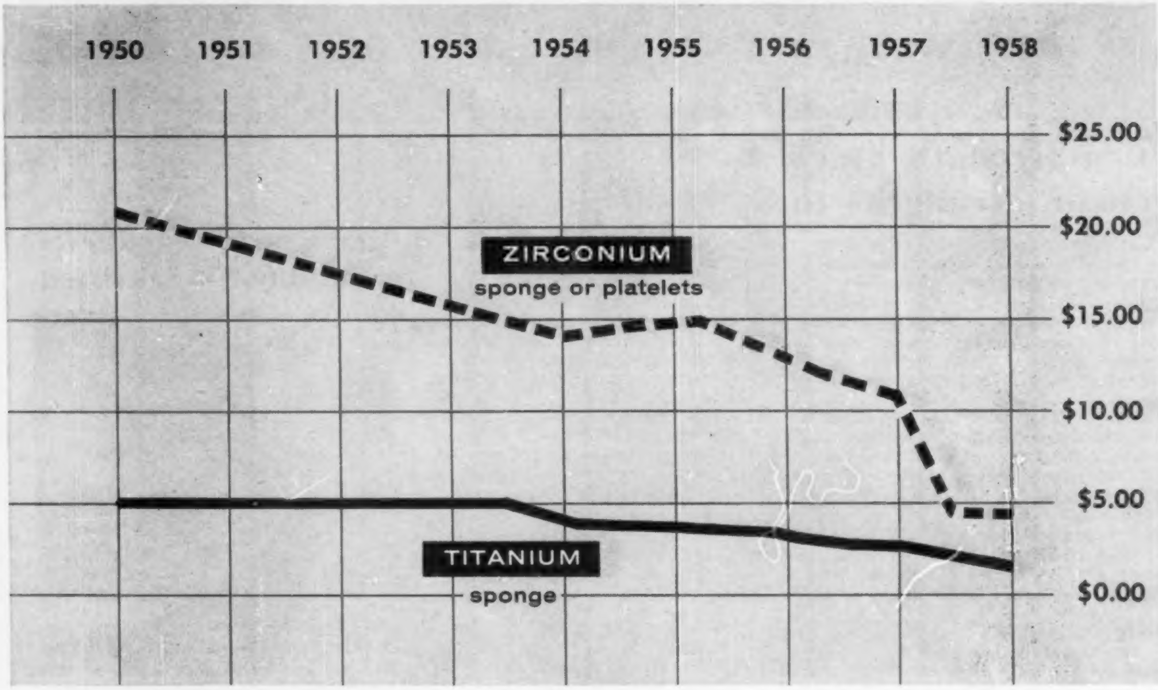
1 2 3 4 5 6 7

Name__________

Company__________

Address__________

City__________



Available soon at lower prices

ZIRCONIUM AND TITANIUM FOR INDUSTRIAL USE

Now is the time to do some new thinking about titanium and zirconium. These metals with their many advantages will soon be *much more plentiful* at *much lower cost.* Reason: U.S.I. will be coming onstream shortly with a 10-million pound per year titanium plant AND a zirconium plant which will supply one million pounds of that metal to industry.

Zirconium from the new plant will sell for considerably less than current prices. Here's why: U.S.I. will use the most economical production technique ever developed for reducing metallic chlorides – a semi-continuous sodium reduction process. This process has possibilities of reducing titanium prices in the future as well.

So think again about zirconium and titanium for industrial equipment. Remember that they are lighter than other metals – a pound goes farther. Remember that they are more durable than other metals–a fabricated product lasts longer.

Write to Bill Greenleaf, U.S.I. Manager of Metals Department, for more information on these new metals from U.S.I.

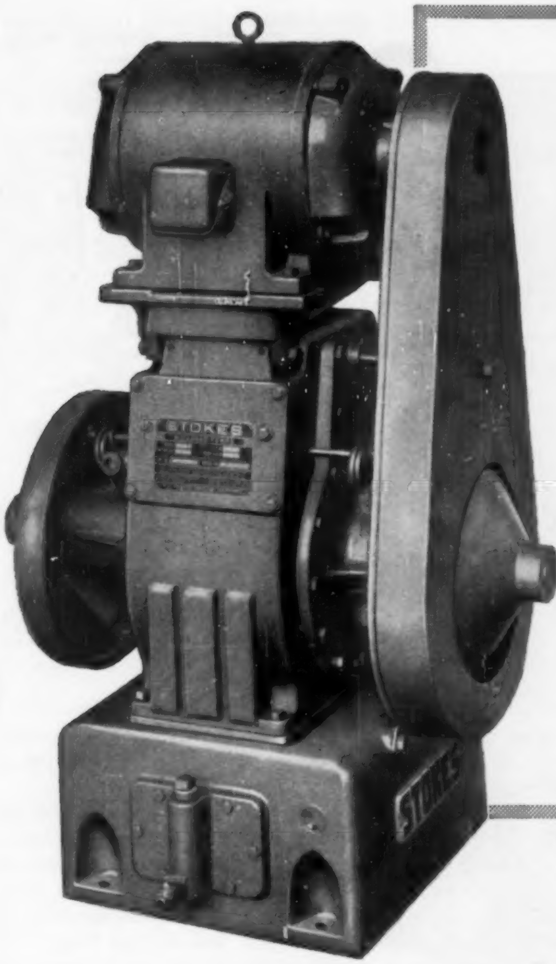
WHAT CAN YOU DO WITH TITANIUM AND ZIRCONIUM AT LOWER PRICES?

In the future titanium sponge prices are expected to drop to about $2.00 a pound, with a corresponding drop in the prices of mill products. At these prices the exceptional strength-to-weight ratio and corrosion resistance of titanium can be put to work in the aircraft, marine, automotive, chemical and allied fields.

Or consider the eventual price of U.S.I. commercial grade zirconium: an estimated $3.00 a pound for platelets and 2 or 2½ times this price for the average mill product. This price will make zirconium practical for chemical equipment, marine equipment, food equipment and surgical metals among other uses. Zirconium has light weight, high structural strength, excellent corrosion and heat resistance; and reactor-grade zirconium has outstanding nuclear properties.

U.S.I. INDUSTRIAL CHEMICALS CO.

Division of National Distillers and Chemical Corporation
99 Park Avenue, New York 16, N. Y.



VERTICAL DESIGN

vacuum pump saves you floor space

If floor space for your vacuum system installation is a problem, here's an "assist" from Stokes. Special Stokes vertical design cuts floor space requirements. For example, the 130 cfm Model 212 Microvac measures less than 3 feet on a side . . . makes your entire set-up smaller.

And together with these features of compactness, you get a 15% increase in pumping capacity . . . at no increase in price. In this way, Stokes Microvac pumps measure up as the standard of comparison for reliable, low-cost performance.

Here's what you get with the Microvac line:

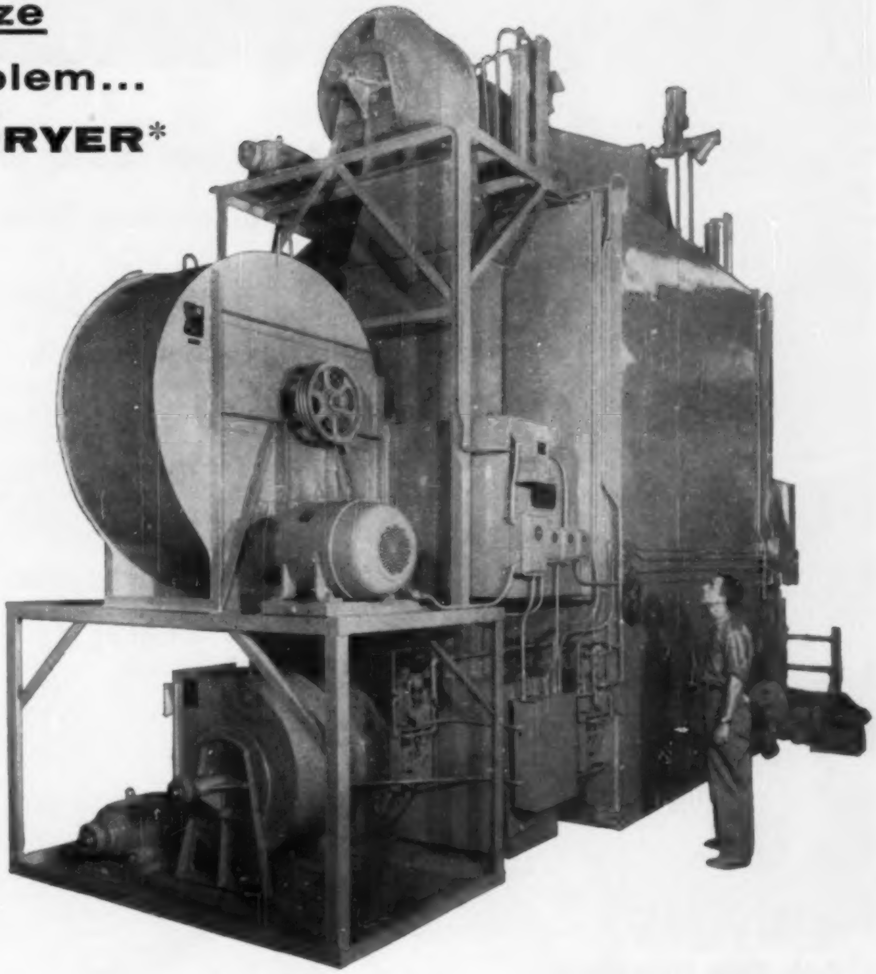
- Minimum maintenance—mechanical face seal eliminates oil leakage at shaft. No stuffing boxes. Fully automatic lubrication.
- Wide pressure ranges—new exhaust valve design assures trouble-free operation during extended pumping periods, in the high pressure range.
- Dirt troubles prevented—intake screen filter traps dirt, scale and other damaging solids.
- Added protection—new oil filter in the line supplies extra protection to bearings and shaft seal.

Microvac pumps give you the high efficiency you want . . . used separately or as roughing pumps with diffusion or booster pumps. Write for catalog 752, "Stokes Microvac Pumps for High Vacuum"; Booklet 755, "How to Care for Your Vacuum Pump" . . . or call your nearest Stokes office to find out how we can help you solve your particular vacuum application problem.

Vacuum Equipment Division
F. J. STOKES CORPORATION
5500 Tabor Road, Philadelphia 20, Pa.

STOKES

For any-size drying problem... LECTRODRYER*



To dry 12,000 cubic feet of air per minute . . . to 50° below zero! That's the guaranteed DRYing capacity of this huge Lectrodryer that safeguards sensitive molten metal against attack by moisture.

The Lectrodryer shown above is a very-special-purpose drier . . . a giant compared to what you may need. But you can have the same breed of efficiency and reliability in a Lectrodryer that meets your needs exactly . . . even a little fellow to handle a few cubic feet of air, gas or organic liquid per hour.

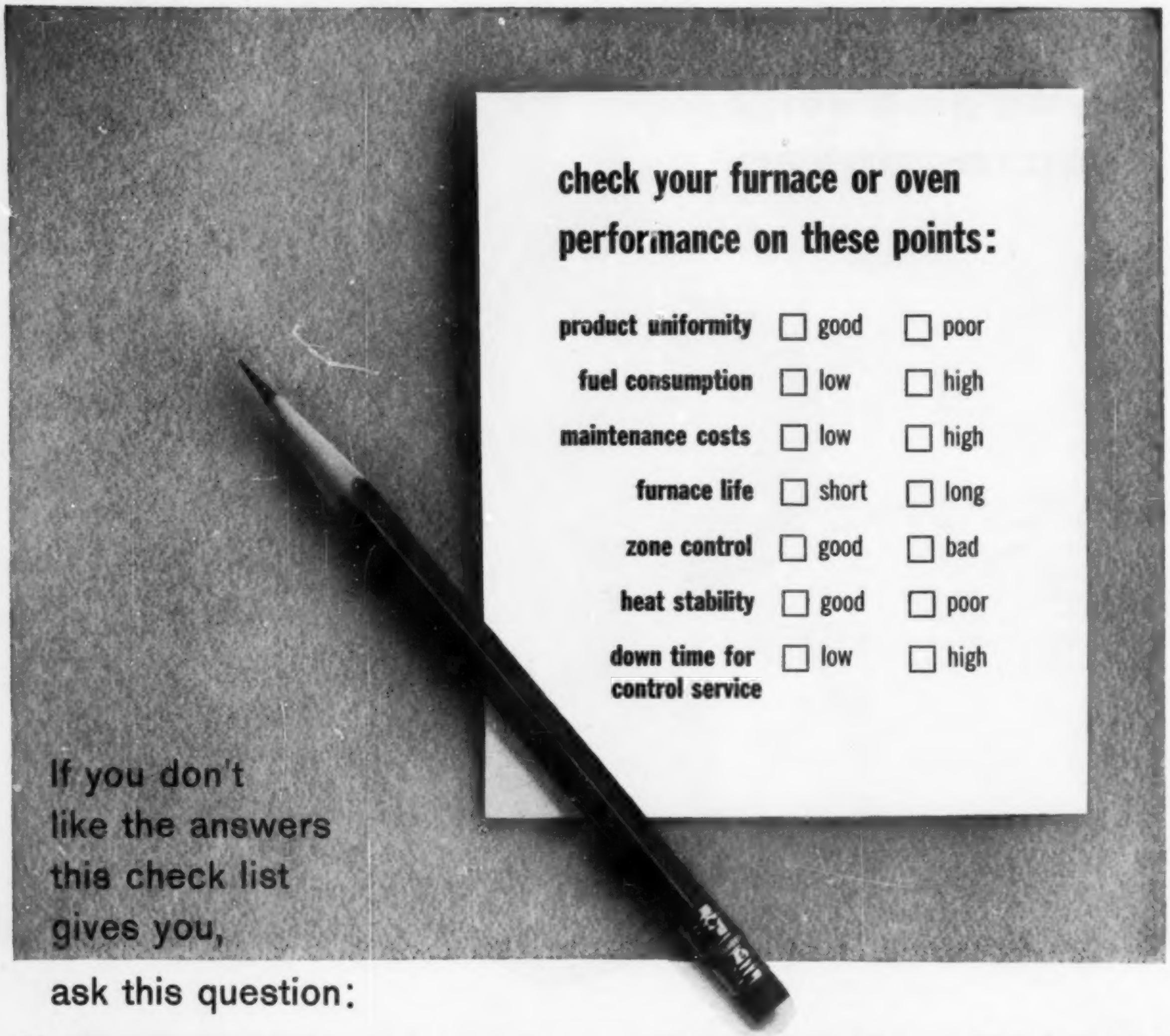
Our wide experience has resulted in *proven* design and construction techniques that are readily adaptable to all types of requirements. No matter what capacities, temperatures, pressures or other factors are involved, we can doubtless supply a guaranteed-performance Lectrodryer to do the job.

Lectrodryer's thoroughly-tested, broadly-applied principles save you costly engineering and building time . . . and the DRYing installation usually costs less than a "build-it-yourself" drier.

Stop the attack moisture is making on your product or processing operations the fast, sure way. Whether DRYing requirements are big and tough, or relatively small and uncomplicated . . . ask for a Lectrodryer quotation today. Pittsburgh Lectrodryer Division, McGraw-Edison Company, 317 32nd Street, Pittsburgh 30, Pennsylvania.

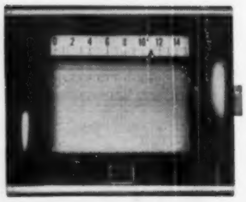
Lectrodryer

*REGISTERED TRADEMARK U. S. PAT. OFF.



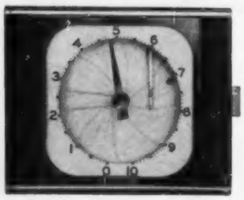
ask this question:

"Are my furnace controls obsolete?"



Strip-chart model

BRISTOL DYNAMASTER* ELECTRONIC PYROMETER CONTROLLERS



Round-chart model

Outmoded instruments can cost you money, lower product quality, and cut output of any furnace or oven.

New Bristol ideas are revolutionizing many older concepts of automatic control. *Bristol's great strides in electronic potentiometer development have made obsolete many instruments only a few years old.*

New product developments and production methods are placing new and unusual demands on furnace instruments and controls today.

That's why it pays to find out about the latest Bristol engineering developments before you buy another instrument or control. Take Continuous Standardization, for example—a feature you'll want on *your* next pyrometer controller. This exclusive Bristol feature, found only on Dynamaster* Pyrometers, eliminates dry cells but retains the accuracy-insuring standard cell. There's no interruption to control for standardization; no batteries to replace.

Continuous Standardization is just *one* recent Bristol development in the field of pyrometry and temperature control. To find out more, write: The Bristol Company, 106 Bristol Road, Waterbury 20, Conn.

7.16

BRISTOL TRAIL-BLAZERS IN PROCESS AUTOMATION

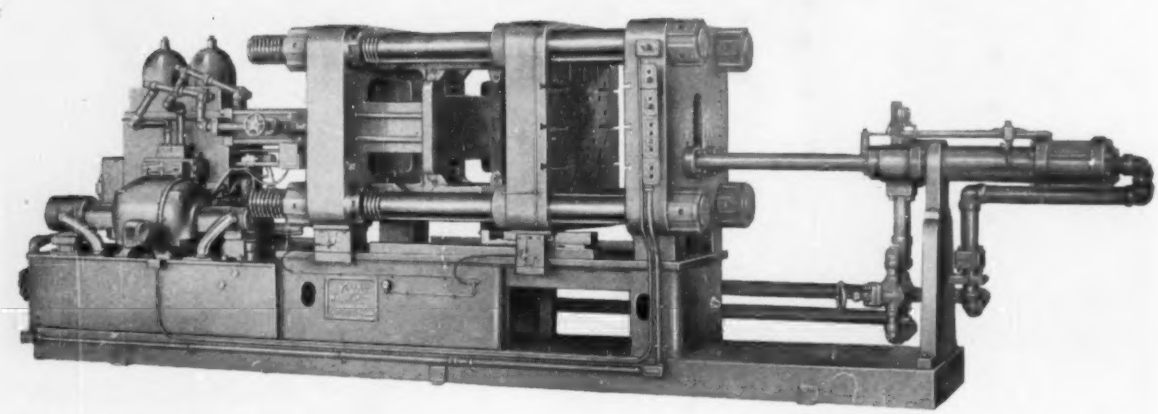
AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

T. M. Reg. U. S. Pat. Off.

PEMCO*

die castings
cut the
world's lawns...and

KUX cuts Pemco's costs



THE MAMMOTH KUX HP-38

Hydraulically operated cold chamber model for the production of die castings from aluminum, brass or magnesium.

Also available in plunger gooseneck model for the production of die castings from lead, tin or zinc

Model BH-38

The rotary lawn mower housing illustrated is an example of the high quality large die castings made by Pemco for leading producers of lawn mowers and other major household appliances. To make them with speed and cost-cutting efficiency, Pemco relies on the mammoth Kux HP-38, with its exceptional capacity for large dies, coupled with ease of mounting, tremendous metal injection pressures and plunger speed.

This one piece aluminum die casting measures 24″ x 24″ and weighs 15 lbs. Produced at an average speed of 60 castings per hour, with the aluminum injected into the die at a pressure of more than 5000 lbs. PSI, a die locking pressure of 750 tons is required. Thus the HP-38, having this capacity, has proven to be the ideal machine to accomplish this die casting job.

If you have a casting problem of unusual size or intricacy, come to Kux, where no die casting problem is too big or too small for our experienced engineers to solve to your advantage.

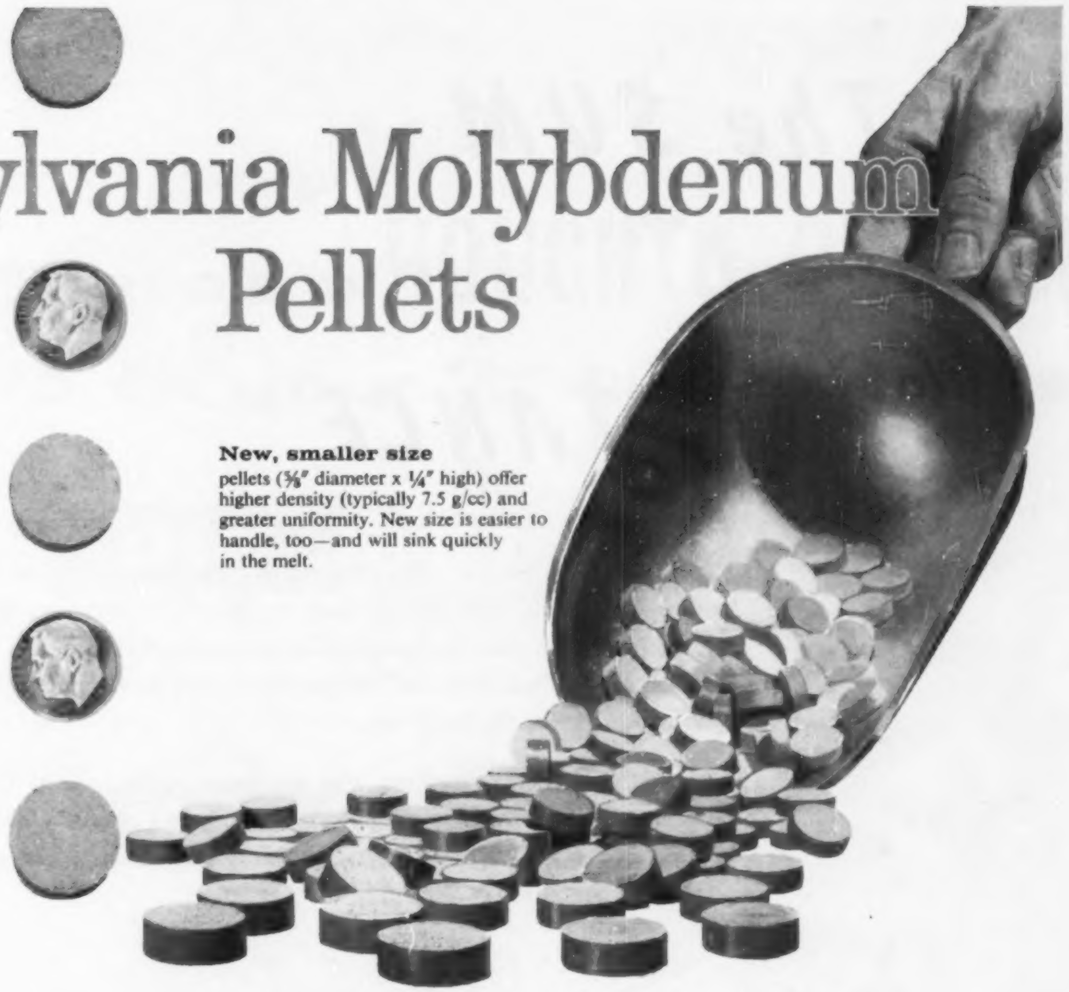
Kux
MACHINE COMPANY

6725 North Ridge Avenue, Chicago 26, Ill.

Builders of a full range of die casting machines... from 25 tons to 1000 tons in size.

*PEMCO, trade name of PRODUCT ENGINEERING AND MANUFACTURING CORPORATION, Bridgman, Michigan, uses many sizes of KUX Die Casting Machines to produce top quality die castings for industry.

Sylvania Molybdenum Pellets



New, smaller size
pellets (⅜″ diameter x ¼″ high) offer higher density (typically 7.5 g/cc) and greater uniformity. New size is easier to handle, too—and will sink quickly in the melt.

—the new form manufactured to <u>specified</u> purity and composition

Sylvania Molybdenum Pellets are designed and manufactured specifically for use in vacuum melting. They provide a readily available source of the best purity molybdenum (typical 99.85%) available on the market. Detrimental impurities are at an extremely low level. This consistent high purity simplifies the calculation of additions to each melt as the usual variations of purity and gas content are eliminated.

By maintaining a high density, the gas content of the pellets is kept well below that acceptable for vacuum melting. In addition, the compact uniform size of the pellets facilitates weighing and charging to the melt.

When you use Sylvania Molybdenum Pellets, you benefit in other ways, too. Their continuous availability means you can plan your production schedules on a long-range basis. Further, their pricing stability permits you to price your own product without having to worry about fluctuating raw materials costs.

Call your Sylvania representative or write for details.

SYLVANIA ELECTRIC PRODUCTS INC.
Chemical and Metallurgical Division
Towanda, Pennsylvania

TUNGSTEN • MOLYBDENUM • CHEMICALS • PHOSPHORS • SEMICONDUCTORS

SYLVANIA

LIGHTING • RADIO • ELECTRONICS • TELEVISION • ATOMIC ENERGY

There's a HOUGHTO-QUENCH to fit your "S" Curve needs

SPEED... The fastest quench this side of water—if you need it. Or a slower speed oil, if that is required.

New magnetic Quench test, demonstrated at 1957 Metal Show, has proved Houghto-Quench "K" fastest oil on the market today.

SURETY... Uniform quenching results, heat after heat, month after month.

STABILITY... No breakdown, no sludge, no light ends to "crack off," for Houghto-Quench is fortified for stability and long life.

Ask your Houghton Man or write
E. F. Houghton & Co., 303 W. Lehigh Avenue
Philadelphia 33, Pa.

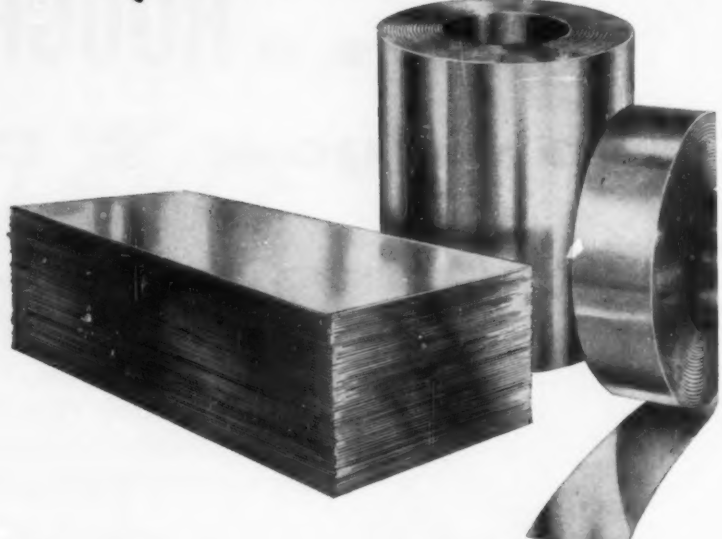
HOUGHTO-QUENCH

... a product of

E. F. HOUGHTON & CO.
PHILADELPHIA • CHICAGO • DETROIT • SAN FRANCISCO

Ready to give you on-the-job service ...

Wherever you are you get *quick personal service*



when you order *MicroRold*® Stainless Steel Sheet & Strip

SPECIFICATIONS

	WIDTH	THICKNESS
SHEETS	up to 36″	.005 to .109
	up to 48″	.010 to .109
STRIP	up to $23\frac{15}{16}$″	.0015 to .090
GRADES:	201, 202, 301, 302, 304, 305, 316, 321, 347, 403, 410, 430 and Micro-Mach (special extra-high-tensile aircraft grade)	

Any one of the 305 independent steel warehouse distributors stocking MicroRold Stainless Steel is ready to serve as your *personal* stainless procurement representative. Located strategically in the U. S. A., Canada and Europe, your MicroRold distributor carries a variety of grades, widths, thicknesses and finishes and is fully qualified to assist you in the selection and fabrication of the most suitable stainless grade for your particular requirements.

Your MicroRold stainless steel distributor assures you of the fastest possible deliveries with an absolute minimum of red tape in order processing. If he is unable to fulfill your needs from stock he has available direct and immediate service from our mill. In cases of emergency, it is possible for us to roll and ship MicroRold Stainless Steel the same day the order is received.

You can rely on MicroRold service as a dependable source of supply, either mill or distributor delivery.

Write, wire or phone today for the name of your nearest MicroRold Stainless Steel Distributor.

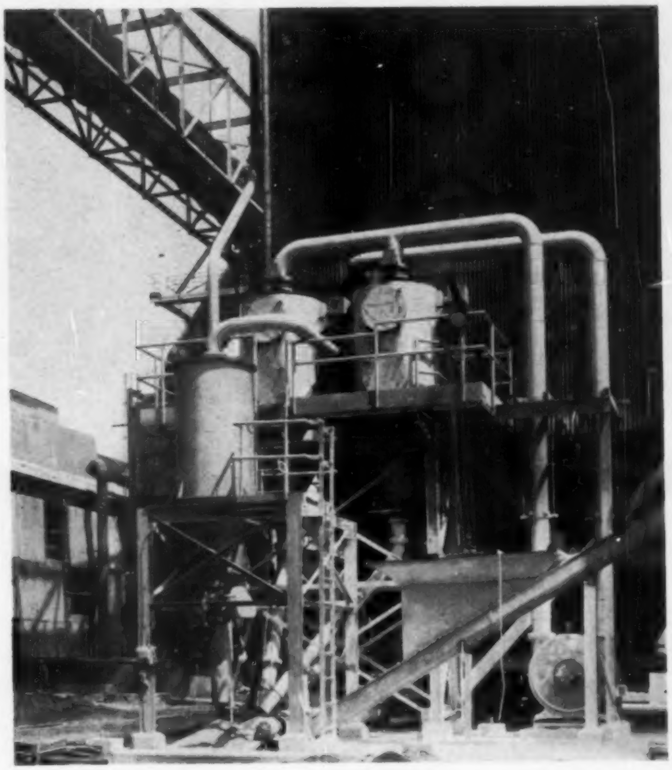
WASHINGTON STEEL CORPORATION

12-T WOODLAND AVENUE WASHINGTON, PENNSYLVANIA

SPENCER VACUUM SYSTEM

handles both **CONVEYING and CLEANING**

. . . at this Metals Plant



A single SPENCER vacuum system handles two big jobs—pneumatic conveying and cleaning—at this modern metals plant.

Pneumatic Conveying of lead, zinc and copper dust is quick, dust-free and economical. Heavy material which settles out in breeching connecting the smelter to the Cottrell drops into hoppers. Once a day these hoppers are emptied by opening a slide gate valve. The accumulated heavy dust drops into a 6" Spencer vacuum line and is whisked away. Material thus recovered is returned to the smelter and melted over again—effecting an important saving for the company.

Cleaning, carried on whenever system is not being used for conveying, is done with standard 1 ¾" and 2" Spencer hose and tool equipment. The *positive, dust-free* sanitation that this bonus use of vacuum makes possible does more than assure plant cleanliness. It also *guards the health* of all employees.

Whatever *your* need in vacuum systems . . . for pneumatic conveying, cleaning, or *both* . . . it will pay you to check with SPENCER—leader in developing systems to meet *individual needs.*

INSTALLATION DATA

Vacuum Producer: 60 H.P. Spencer.
Conveying Capacity: 7½ Tons per hour.
Primary Separator (1): 42" with 8" motor-driven rotary discharge valve.
Secondary Separators (2): 50" bag type with motor-driven bag shakers, automatic sequence timers and solenoid-operated valves.

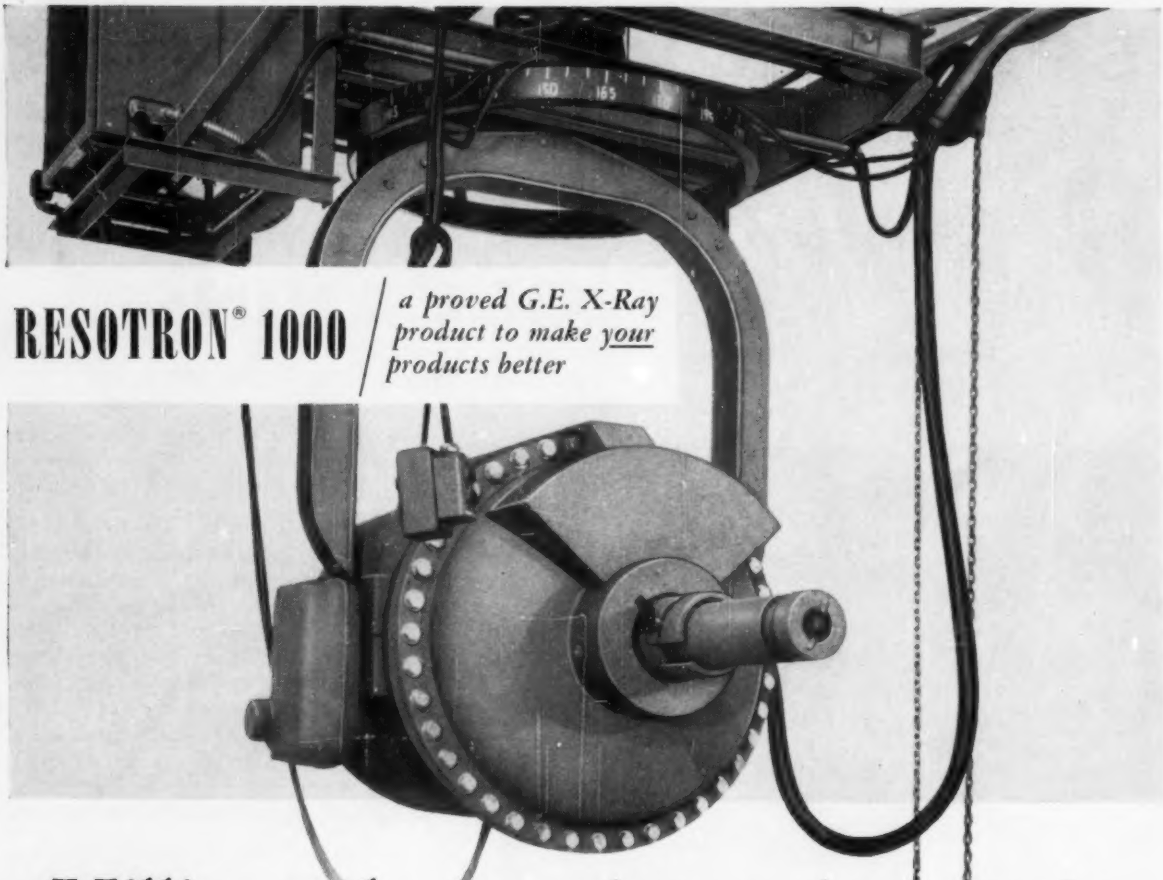
Request these informative Bulletins:
No. 143-B Spencer Pneumatic Conveying
No. 155-B Spencer Vacuum

SPENCER

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

PORTABLE VACUUM CLEANERS

BLOWERS



Million-volt x-ray inspection: *routine*

MISCO speeds 100% inspection of jet blades with radial radiography

Using a G-E Resotron 1000 and a specially designed jig, Misco Precision Casting Co., Whitehall, Mich., now inspects *seven times as many* jet engine turbine blades per exposure as they did with their lower-voltage (250 kvp) equipment. This is just one example of how super-voltage radiography on a mass-production basis can slash the cost of quality control.

To fill your nondestructive testing needs, General Electric offers a complete line of x-ray apparatus—from 140,000 to 2,000,000 volts... for manual, semi-automatic or automatic operation, fixed or mobile. Contact your G-E x-ray representative, or write X-Ray Department, General Electric Co., Milwaukee 1, Wis., for Pub. AS-104.

Progress Is Our Most Important Product

GENERAL ELECTRIC

XXIV

This is the twenty-fourth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Quenching and Tempering Alloy Steels

Of the various methods of heat-treating alloy steels, the most important is that involving quench and temper. This method, which enhances the mechanical properties of the end product, differs materially from normalizing and annealing (previously discussed in this series).

The purpose of quenching is to effect a cooling rate sufficient to develop the desired hardness and structure.

Before quenching takes place, steel is heated to a point above the transformation range. Quenching is the subsequent immersion of this heated steel in a circulated or agitated bath of oil, water, brine, or caustic; or, in the case of austempering or martempering, generally in agitated molten salt baths. Austempering and martempering are preferable where a minimum of distortion is desired.

Quenching *increases* the tensile strength, yield point, and hardness of alloy steels. It *decreases* ductility—that is, elongation and reduction of area. It also decreases resistance to impact. However, by means of tempering, it is possible to restore some of the ductility and impact-resistance—but only at a sacrifice of tensile strength, yield point, and hardness.

The results of mild oil- or wat quenching as related to mass effe can be found in the end-quench hardenability test. Voluminous data concerning this test are issued by AISI and SAE in the form of hardenability bands for the various grades of alloy steels.

If thermal cracking is to be avoided, cooling by liquid quenching should not be carried to a point below 150 deg F. When a temperature of 150 deg F is approached, immediate tempering should follow. Because of residual stresses, no steel should be used in the as-quenched condition.

Tempering can be defined as reheating to a specified temperature below the lower critical range, followed by air cooling. It can be done in furnaces, oil, or salt baths, the temperatures varying from 300 to 1200 deg F. With most grades of alloy steel, it is best to avoid temperatures between 500 and 700 deg because of the "blue brittleness" that occurs in this range. Maximum hardness and wear-resistance result from tempering at low temperatures; maximum toughness is achieved by tempering at the higher levels. Of course, one of the essential reasons for tempering is to relieve the residual stresses set up in quenching.

Bethlehem metallurgists have devoted years of study to quenching, tempering, and other phases of heat-treating. By all means call them if they can be of service to you. And please remember, when you are next in the market for alloy steels, that Bethlehem makes all AISI standard grades, as well as special-analysis steels and the full range of carbon grades.

If you would like reprints of this series of advertisements from No. I through No. XX, please write to us, addressing your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa. The first 20 subjects in the series are now available in a handy 36-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Exclusive with the Heroult:

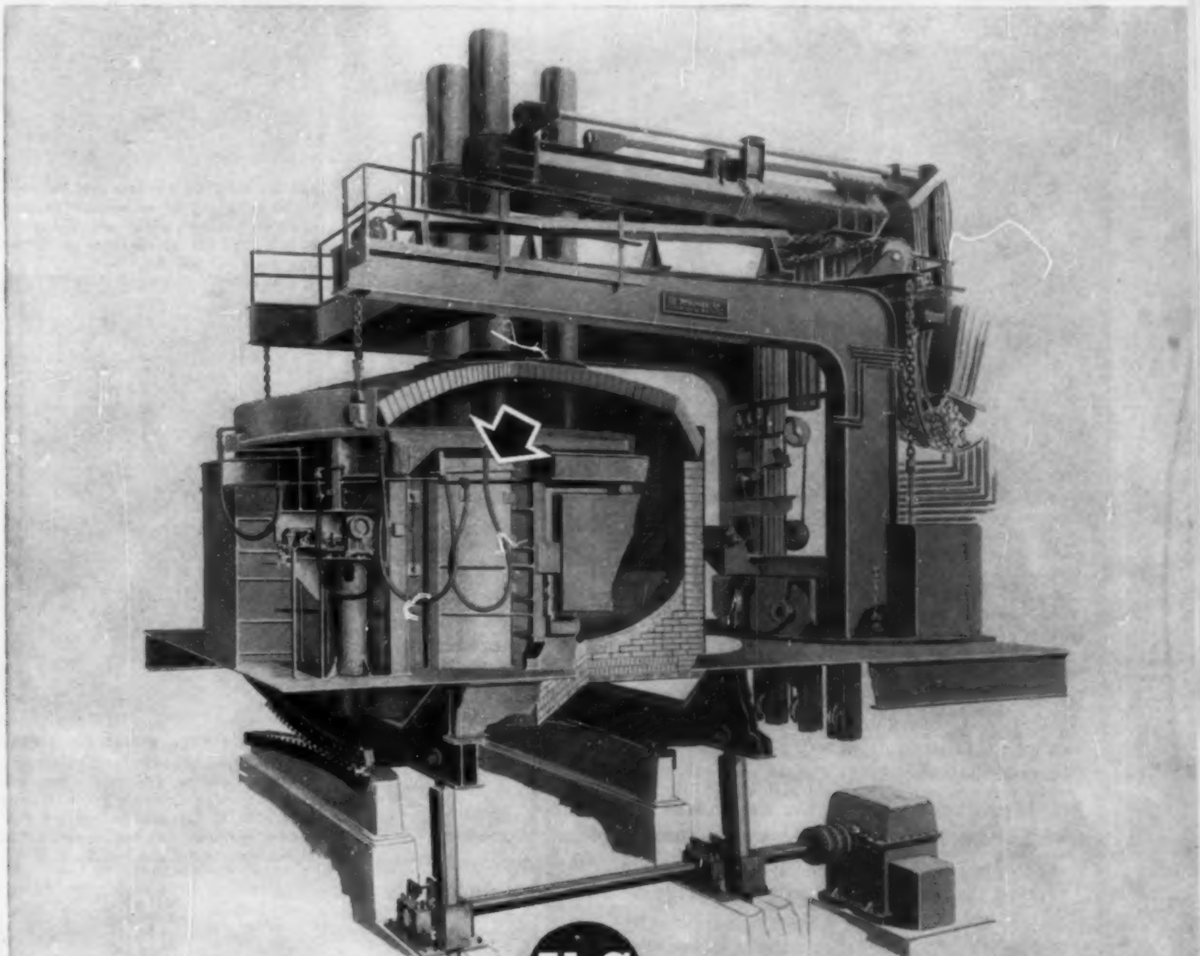
Cage-Type Shell Construction

The Heroult is the only electric furnace on the market with a cage-type shell. In this exclusive design, the shell plates are loosely attached to a heavy structural supporting cage, which allows the plates to expand and contract freely, thus minimizing shell distortion due to extreme changes in temperature. This type of construction also permits easy replacement of damaged shell plates.

This cage-type shell construction is just one of the many advantages you get in the Heroult—advantages which make for performance efficiency, operating economy, and low-cost maintenance. Other exclusive features are: 100% mechanical operation; independently supported operating mechanism; flat bottom shell; and skew back roof ring.

The new Heroult Electric Melting Furnaces are available in sizes of shell diameter ranging from 7′ 0″ up, and with capacities of from 6,000 lbs. up to 400,000 lbs. and greater. They can readily be furnished with a non-magnetic shell bottom section to accommodate induction-stirring equipment. Gantry-type top-charge furnaces, door-charge furnaces, and special furnaces for duplexing and non-ferrous melting can also be supplied.

We welcome an opportunity to help you select and install the Heroult best suited to your requirements. An inquiry to the nearest office will bring complete details.



Heroult

ELECTRIC MELTING FURNACES

USS

AMERICAN BRIDGE DIVISION

UNITED STATES STEEL CORPORATION, GENERAL OFFICES:
525 WILLIAM PENN PLACE, PITTSBURGH, PA.

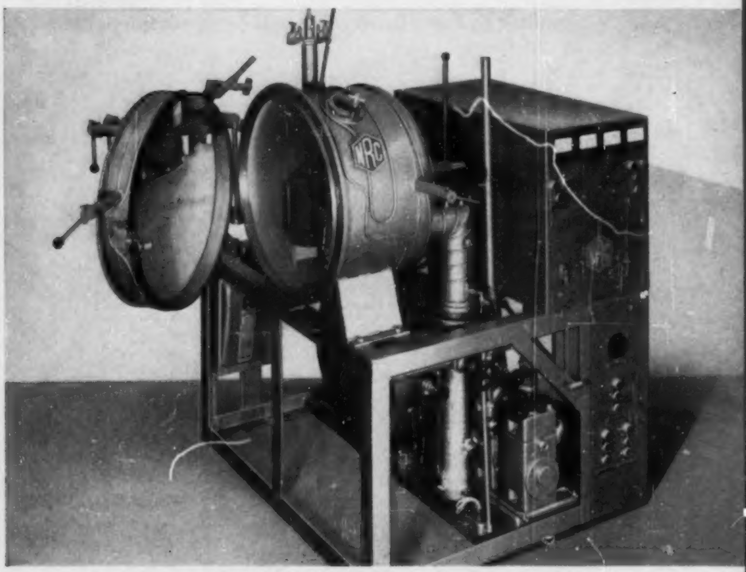
Contracting Offices in New York, Philadelphia, Chicago, San Francisco and other principal cities.
United States Steel Export Company, New York

SEE THE UNITED STATES STEEL HOUR. It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

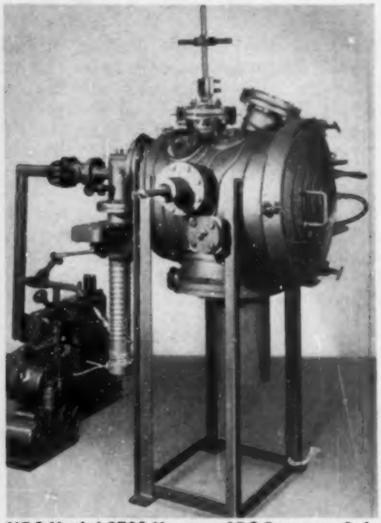
UNITED STATES STEEL

Get Started Easily In Vacuum Metallurgy

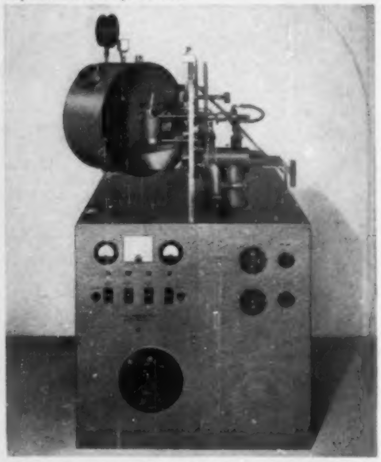
NRC experience and standard ARC, INDUCTION and RESISTANCE furnaces can remove the mystery from vacuum metallurgy



NRC Model 2551 Vacuum INDUCTION Furnace. Packaged facility for melting, purifying, alloying, casting and heat treating. Capacity 12 lbs. Other standard and special induction furnaces with capacities up to 5000 lbs.



NRC Model 2703 Vacuum ARC Furnace. Safe and versatile unit for consumable or nonconsumable electrode melting into cold mold or skull (consumable head not shown). Other arc furnaces with capacities to 10,000 lbs.



NRC Model 2904-B Vacuum RESISTANCE Furnace. Over 100 now in use for melting, purifying, alloying, casting, sintering, brazing, annealing, and heat treating. Capacity 2-8 lbs. Temperature above 2000°C. Pressures to 10^{-5} mm Hg. Other standard resistance bell, muffle, and pit furnaces with hot zones to 54" dia. by 12'.

If you're considering vacuum metallurgy as part of your product improvement or quality control program, you don't have to start from scratch. You can get a head-start by drawing on the experience NRC has gained from building and operating more high vacuum furnaces than any other organization in the world. You can easily find out

- If vacuum metallurgy can help you as it has others.
- Whether you really need to run your own development program.
- What type of furnace would be most suitable for your program.
- How to avoid the expensive pitfalls which have so often trapped beginners.

Then, if you decide to run your own development program, you'll find you can get started easily, economically and quickly with a standard NRC furnace, such as those shown here. You won't need a vacuum expert to run it either. NRC furnaces are designed for simplicity, and our engineers will teach you up-to-date operating techniques. This is the way for you to get useful results sooner, with a minimum investment in equipment, time, and operating costs.

Get started easily by writing for more information today.

NRC
NRC EQUIPMENT CORPORATION

DEPT. IM, CHARLEMONT ST., NEWTON 61, MASS.
A Subsidiary of National Research Corporation

Profit by UDDEHOLM'S Complete Service In Precision Ground Tool Steel

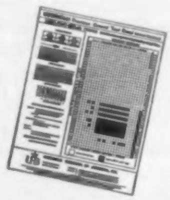
Two new Uddeholm features—features that continue their benefits *after* delivery—now add further convenience to your use of Precision Ground Tool Steel.

Rust-Preventive Envelopes Each piece of Uddeholm Ground Flat Stock is now wrapped individually in corrosion-inhibiting VPI paper. You can use these envelopes to store degreased steel indefinitely without danger of rust.

Special Marking Quick, sure identification of unwrapped steel is now assured by several electro-etch markings on each piece.

And don't overlook these other important reasons why Uddeholm continues to be your most reliable source for Precision Ground Tool Steel: A tremendous selection of available sizes to meet your needs more closely—Choice of oil-hardening UHB-46 (SAE O1) or air-hardening UHB-151 (SAE A2)—A world-wide reputation of tool steel quality, guaranteeing you the finest performance possible—Ample warehouse stocks and fast service to get your *complete* order to you without delay.

Write for this handy, 8½" x 11" stock size chart of Uddeholm Precision Ground Tool Steels



UHB

UDDEHOLM COMPANY OF AMERICA, INC.

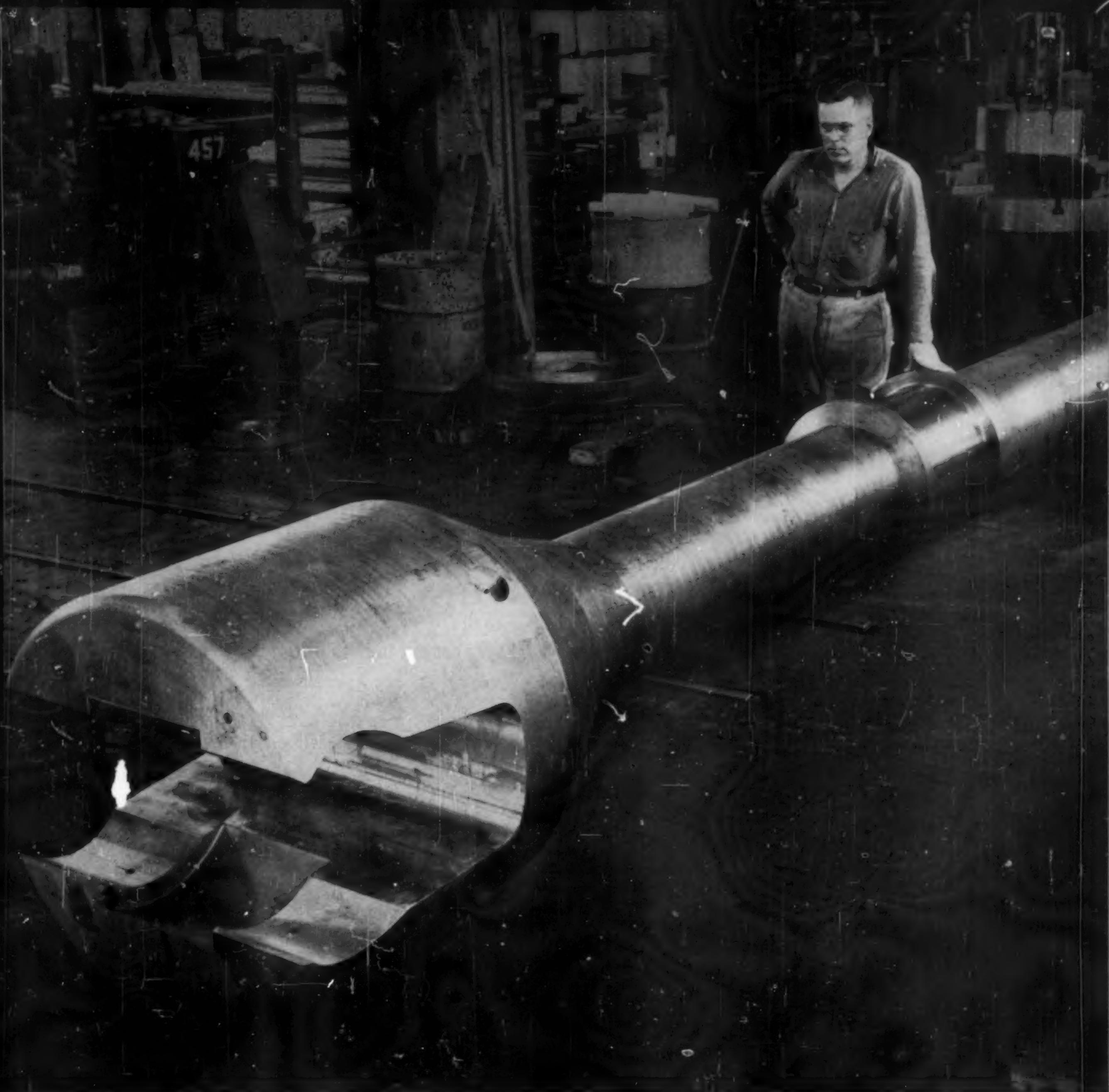
Tool and Die Steels
Specialty Strip Steels

Offices and Warehouses

New York: 155 East 44th Street, MUrray Hill 7-4575
Cleveland: 4540 East 71st Street, DIamond 1-1110
Los Angeles: 5037 Telegraph Road, ANgelus 2-5121

District Representatives

CHICAGO: Frank J. Mackin, Leroy E. Marshall, 55 East Washington, STate 2-1649 DETROIT: Warren H. Nugent, 17304 Lahser Road, KEnwood 5-6340
PHILADELPHIA: Frank T. Campagna, 34 South 17th Street, RIttenhouse 6-4290



WHO FORGES THE TOUGH ONES? *& machines them, too*

You're looking at a universal spindle and coupling for a 38" slabbing mill. It's nearly 20 feet long and weighs 20,000 pounds. That's a lot of forging—*and we made it!*

The trade knows us as *specialists* in forgings of this large size. We have the experience, specialized talent, and the kind of equipment needed to make couplings, crankshafts, or any other large-size forging, from the basic electric steel to the finished machined part . . . all done in our completely integrated plant.

This is our specialty—large commercial forgings. Yes, for over 43 years the trade's answer to "who forges and machines the tough ones . . . best" has been

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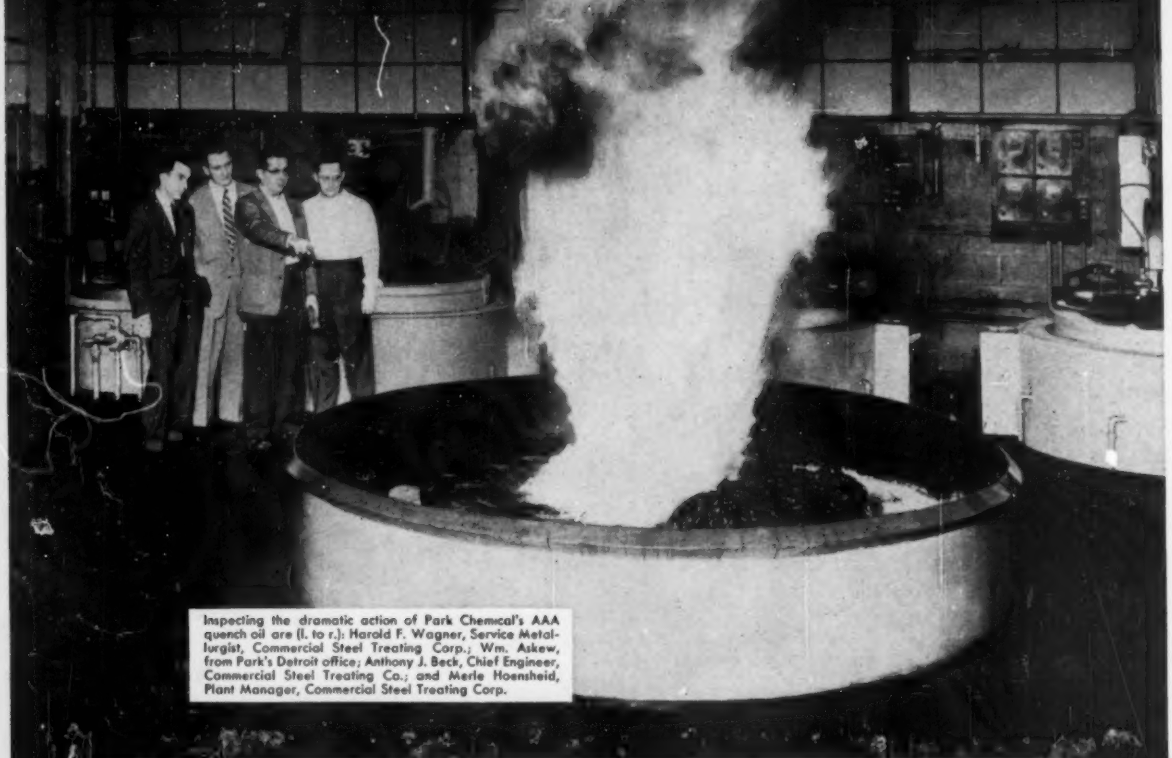
IRVINE (WARREN COUNTY), PENNSYLVANIA

To see more of "the tough ones," and the machinery they're made on, write for Bulletin NFO 2.

Here's Proof that Park AAA Gives QUICK-QUENCHING Action!



Inspecting the dramatic action of Park Chemical's AAA quench oil are (l. to r.): Harold F. Wagner, Service Metallurgist, Commercial Steel Treating Corp.; Wm. Askew, from Park's Detroit office; Anthony J. Beck, Chief Engineer, Commercial Steel Treating Co.; and Merle Hoensheid, Plant Manager, Commercial Steel Treating Corp.

Here you see the dramatic action of Park Chemical Company's AAA Quench Oil, a faster cooling yet extremely long-lasting quench oil. Park AAA provides higher and more uniform hardness, with little or no distortion, warping, or cracking. To quote Merle Hoensheid, General Manager of the Stephenson Highway plant of the Commercial Steel Treating Corporation, Detroit: "We have learned to *depend* on the more than satisfactory results from Park's AAA quenching oil."

Park Chemical produces a complete line of heat treating materials bearing the same high quality and dependability of Park's AAA. Highest quality and uniformity are absolutely maintained in *all* Park heat treating products through strict laboratory control from raw material to finished product.

We would be happy to help you work out a solution to your heat treating problems without obligation. Call or write today.

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Unique electrode feed. The high quality of the melts is attained by feeding the consumable* electrodes at optimum rates. An electronic system, the Heratron Control, monitors arc voltage, current, and short circuits—and automatically maintains the arc between ½ and 1 inch in length.

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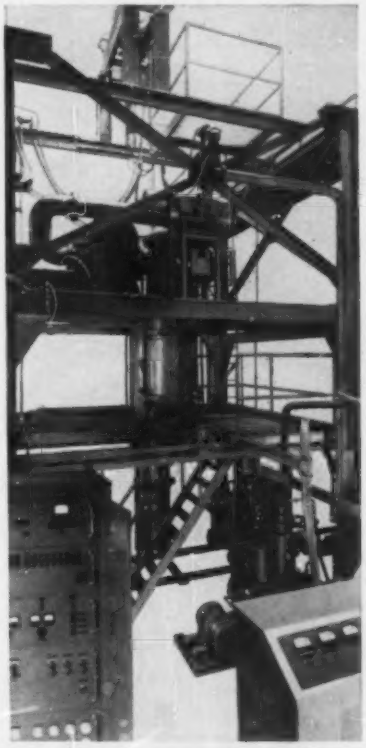
How to purchase. There are five standard models of the Heraeus furnace with capacities from 20 lbs. to 6600 lbs. of steel—and special designs with capacities ranging up to and beyond 10,000 lbs. of steel.

CEC has an exclusive license to sell and service these furnaces, the Roots pumps, and accessories. For a complete discussion of these proved furnaces, write for Bulletin 4-27.

*The smallest of these furnaces also operate with nonconsumable electrodes



Ingots of 16″ diameter can be processed in this Model VA-L 600 sh Heraeus furnace.

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Vacuum Metals Corporation, Division of Crucible Steel Company of America, is the first and largest producer of vacuum-induction melted metals. And VMC produces a wider variety of alloys than any other company. Furthermore, it is now doubling its capacity, to meet increasing industrial demands for these interesting materials. For details on how a vacuum-melted metal may help you solve a tough metal problem, write, giving as much data as possible, to *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, N. Y.*

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Metal Progress

VOLUME 72—JULY THROUGH DECEMBER, 1957

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Grain Refinement of an Aluminum-Tin Bearing Alloy

Digest of "Grain Refinement of Aluminum 6% Tin", by G. L. Foubert and W. C. Winegard, *Canadian Metals*, Vol. 20, February 1957, p. 50 and 52.

THE AUTHORS investigated the effects of mold temperature and a titanium addition on the grain size of an aluminum bearing alloy containing 6% tin. Melts containing aluminum of 99.5% purity and commercial grade tin were made in a clay crucible lined with sodium aluminate, and poured at 1400° F. into a graphite mold. Ingots, weighing about 1.6 lb., were 1½ in. diameter and 2½ in. high. The mold walls were ¾ in. thick.

With an unheated mold (at room temperature) columnar grain growth occurred. A columnar zone extended from the surface inward about ⅜ in. The high temperature gradient in the solidifying ingot caused this type of growth. When the temperature gradient was lowered by pouring the ingot into a mold heated to 660° F., the columnar zone became much thinner. In this case most of the grains were rather coarse and equiaxed due to supercooling of the melt. When the mold temperature was 1200° F., the structure was completely equiaxed, but the grains were about half as large because the very low temperature gradient in this solidifying ingot allowed weak nucleating agents in the aluminum to produce some grain refinement in the supercooled liquid. The mold had to be hotter than 850° F. to obtain an ingot of completely equiaxed structure.

When an addition of 0.1% titanium, or a smaller amount of a mixture of titanium, zirconium and boron, was stirred into this aluminum-tin alloy at 1380° F. with a silica rod, the ingot structure was completely equiaxed and at least ten times finer, whether the mold was at room temperature or hotter. It was concluded, therefore, that the grain size of castings of this aluminum-tin alloy can be refined by the same elements that produce grain refinement in pure aluminum.

G. F. COMSTOCK

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